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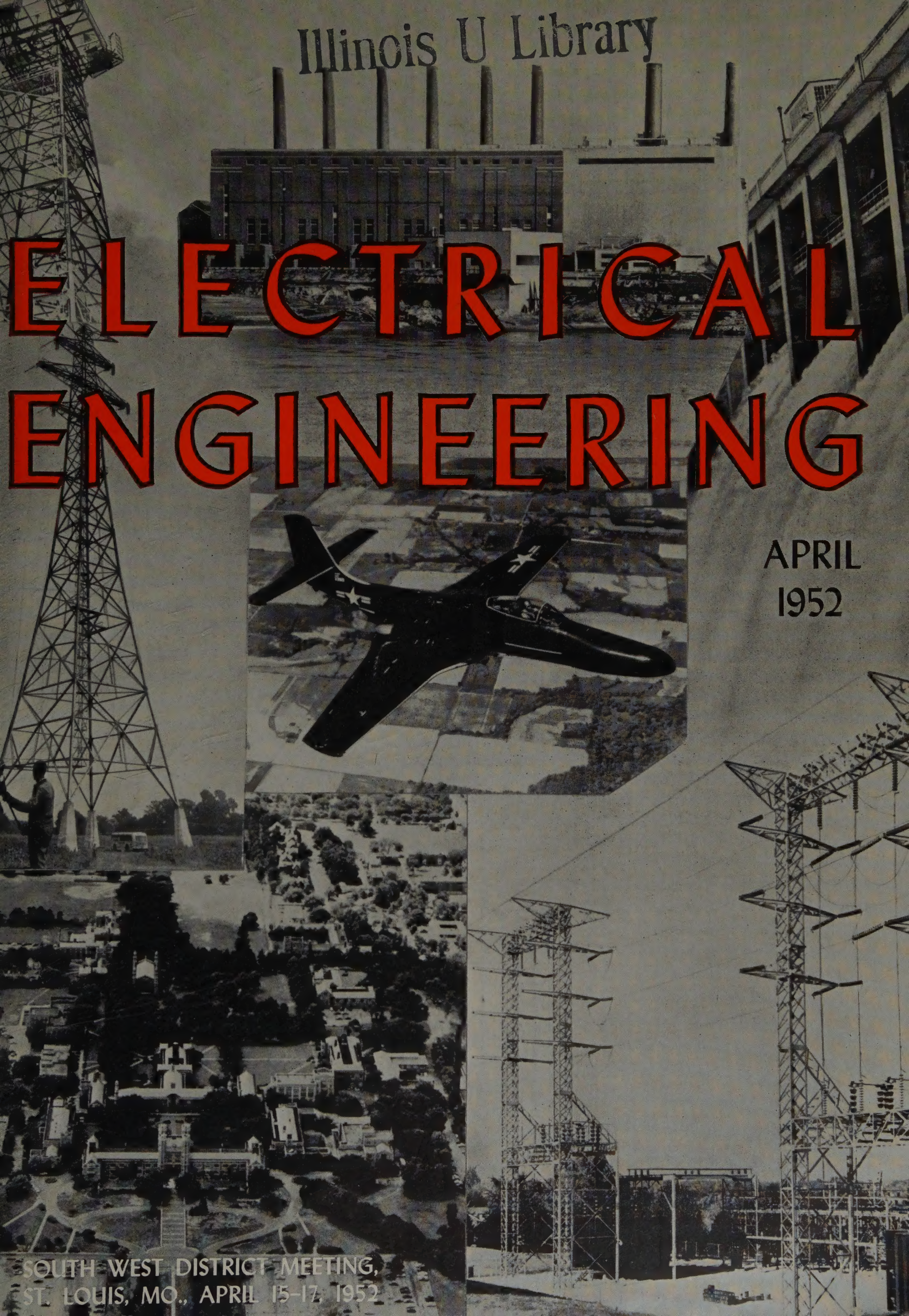
ELECTRICAL ENGINEERING

APRIL
1952



SOUTH WEST DISTRICT MEETING,
ST. LOUIS, MO., APRIL 15-17, 1952

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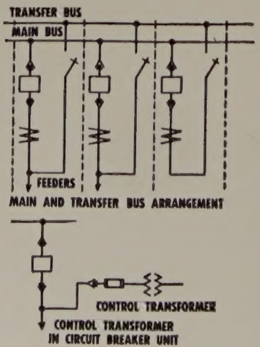
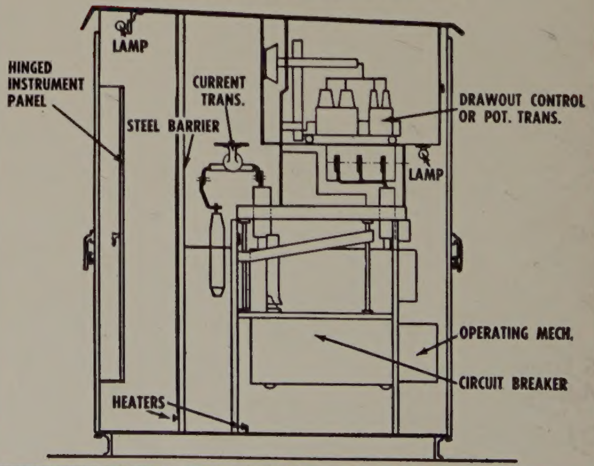

TRANSFER BUS
MAIN BUS
FEEDERS
MAIN AND TRANSFER BUS ARRANGEMENT
CONTROL TRANSFORMER
CONTROL TRANSFORMER IN CIRCUIT BREAKER UNIT

CONSTRUCTION DETAILS



ELECTRICAL ENGINEERING

Registered United States Patent Office

APRIL
1952

The Cover: A composite of scenes in the vicinity of St. Louis, Mo., site of the AIEE South West District Meeting, April 15–17, 1952. Shown clockwise from the upper left-hand corner are a microwave relay tower of the Southwestern Bell Telephone Company, Union Electric Venice plant, Union Electric Bagnell plant, Union Electric 138-kv Watson Substation, Washington University campus, a 138-kv distribution tower, and, in the center, a jet plane of the MacDonnell Aircraft Company.

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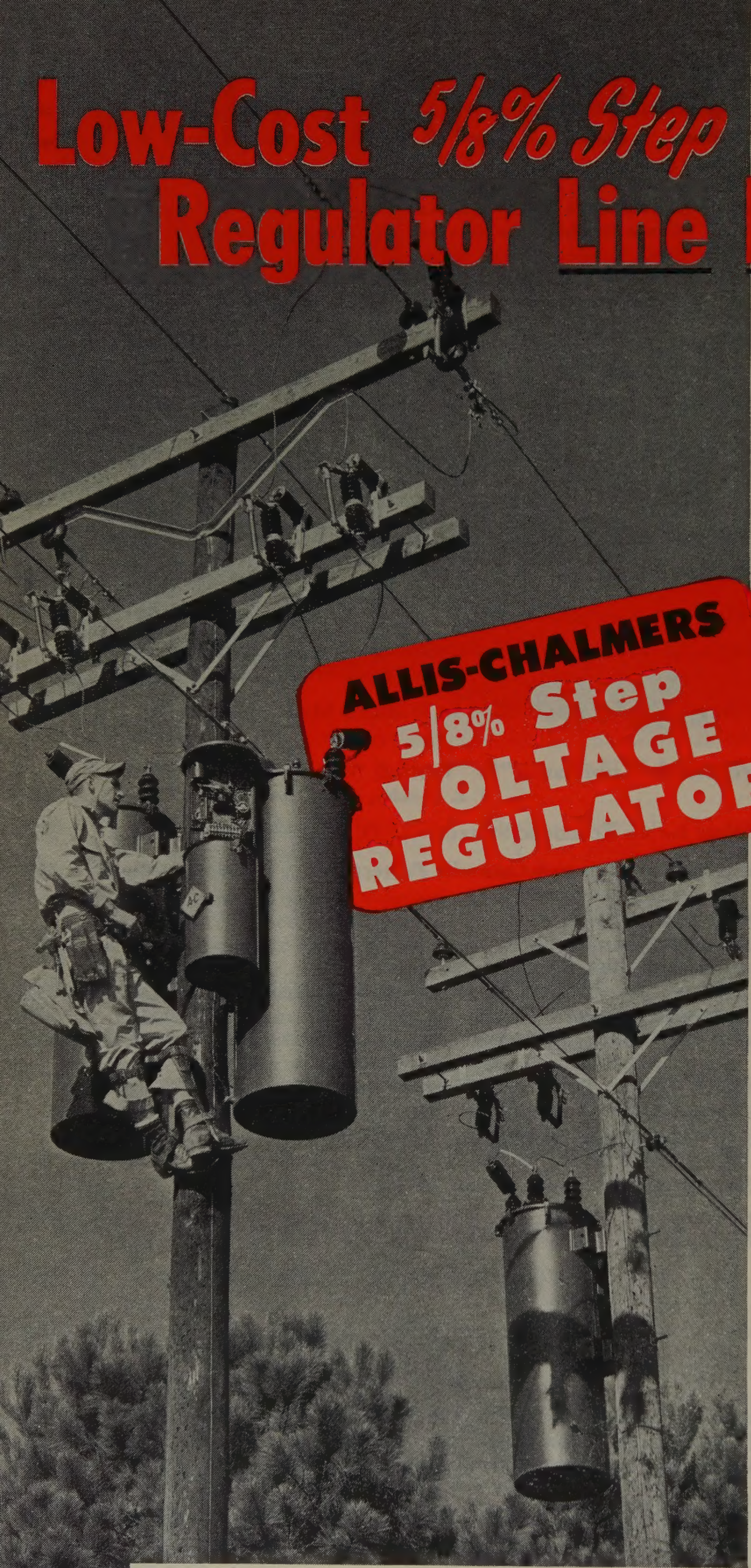
Low-Cost 5/8% Step Distribution Regulator Line Extended



Time-tested JFR regulators can now be used on any feeder

THE EXTENSION of the Allis-Chalmers JFR ⅝% step voltage regulator line to cover five new ratings means that the initial cost of regulation has been reduced for many more feeders. Now you can get time-tested JFR's in the following ratings: 100 amps rated 7620 volts; 50 and 100 amps rated 5000 volts; and 100 and 200 amps rated 2500 volts.

The low price tag on Allis-Chalmers JFR ⅝% step regulator line means that the advantages of voltage regulation can now be brought to marginal lines where equipment costs were too high before. And even though the price tag is low, there's no reduction in quality with the JFR. You get all the advantages of Allis-Chalmers ⅝% step voltage regulation: ⅝% steps, ± 1 volt band, 20% range of regulation, close average voltage maintained by voltage integrator, life long contacts, tap changing and drive mechanism with balanced spring action to eliminate shock, and unit construction for easier maintenance.

Get the complete story on how the Allis-Chalmers JFR ⅝% step voltage regulator line can cut regulation costs for you. Call your nearest Allis-Chalmers district office or write Allis-Chalmers, Milwaukee 1, Wisconsin. A-3622

RATINGS NOW AVAILABLE

7620 volts	5000 volts	2500 volts
15 amp	50 amp	100 amp
50 amp	100 amp	200 amp
100 amp		

ALLIS-CHALMERS

Originators of 5/8% Step Regulators

HIGHLIGHTS........

Coming Meetings. Institute meetings scheduled for the near future include the South West District Meeting (*pages 374–6*), the North Eastern District Meeting (*pages 377–9*), and the Summer General Meeting in Minneapolis in June (*pages 380–1*).

Joint Conferences. With the AIEE as one of its sponsors, the third annual Welding Conference will be held this year in Detroit (*pages 376–7*), while another joint venture, a conference on Progress in Quality Electronic Components, is scheduled for Washington, D. C., in May (*pages 379–80*).

Electrostatic Controls for Hazardous Applications To assist safety engineers and plant personnel in a more discriminating choice of suitable antistatic equipment, this article has been prepared classifying various types of static neutralizers. A number of commercial units are compared as to advantages and limitations, effectiveness, and degree of safety (*pages 329–34*).

Corrosion and Cathodic Protection. A fundamental discussion of the nature of corrosion is given as a contribution to the understanding of the mechanism of cathodic protection and the electrochemistry of the phase boundary. This study, from the electrical standpoint, consists mainly of evaluating the behavior of galvanic couples (*pages 367–73*).

New Electrostatic Tube for Williams Memory System. The development of the Williams memory system in England is considered one of the outstanding features in the computer field. The cathode-ray tubes used in this system are undergoing improvement and this article describes one of the newest memory tubes (*pages 352–6*).

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An Analogue for an Economic System. An extension of the methods of analogous circuits into the field of economics reveals that, on the basis of certain postulates, equations may be written for a macrodynamical economic system. These equations, in turn, lead to an electronic circuit analogue from which information useful to the investor can be obtained (*pages 362–6*).

The Bevatron Power Plant. Supplying power to a magnet which has a peak power input at maximum field of 100,000 kw and stores magnetic energy of about 82,500 kilowatt-seconds at that peak requires a high degree of power plant engineering. Such an installation at the University of California's new bevatron is described (*pages 338–43*).

Co-ordinated Transportation for Metropolitan Communities. Moving people to and from large communities as well as about them has become a major problem, which has not been aided to any great extent by extending and enlarging highways. One of the possible solutions is greater use and extension of electric transportation systems as described in this article (*pages 324–7*).

A Job Rotation Executive Development Program. An evaluation is given of the effectiveness of the executive development program at the Consolidated Edison Company of New York. The program consists mostly of job rotation, has been in progress about ten years, and has some 200 graduates now with the company (*pages 305–10*).

Objectives of Engineering Education. The strength of a nation is not determined by its conquests, but by its effectiveness in the use of its physical and mental resources. So states Prof. A. G. Conrad, Chairman of the Department of Electrical Engineering of Yale University's School of Engineering, in this article which reiterates the fundamental aims of engineering education (*pages 335–71*).

The Human Link in Control Circuits. As part of a closed-loop circuit, the human operator is a vital element in many control functions. For this reason, circuit engineers must understand thoroughly the capabilities and limitations of the human link to achieve fullest design possibilities. In other words, he must take into account "Human Engineering" (*pages 319–24*).

Very-High-Frequency Radio Communication in Train Operation One of the major problems encountered in the operation of a railroad is the reliability of communication. Until a few years ago, it was impossible for a dispatcher to talk with a train crew unless the train was in a station. With the advent of very-high-frequency radio, dispatcher and crew can now converse while the train is under way. The equipment is described in the article on pages 312–17.

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions.*

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Affiliates, Associate Members, Members, and Fellows.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Mar '51, p. 35A	Winter General
July '51, p. 23A	Southern District North Eastern District Great Lakes District Summer General
Nov '51, p. 37A	Pacific General Fall General

Lubrication of Water Wheel Thrust Bearings. The application of hydrostatic lubrication to water wheel thrust bearings during starting may be accomplished by two methods described in this article. One is by means of an externally pressurized system; the other uses an automatic hydraulic lifting system for establishing an oil film during the initial starting period (*pages 357–62*).

Transmission Substation Structural Design. The AIEE Committee on Substations offers a report with recommendations for the use of light metals and steel in the station structures. A classification of structures is presented also (*pages 344–50*).

Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grades, qualifications, and fees may be obtained from Mr. H. H. Henline, Secretary, 33 West 39th Street, New York 18, N. Y.

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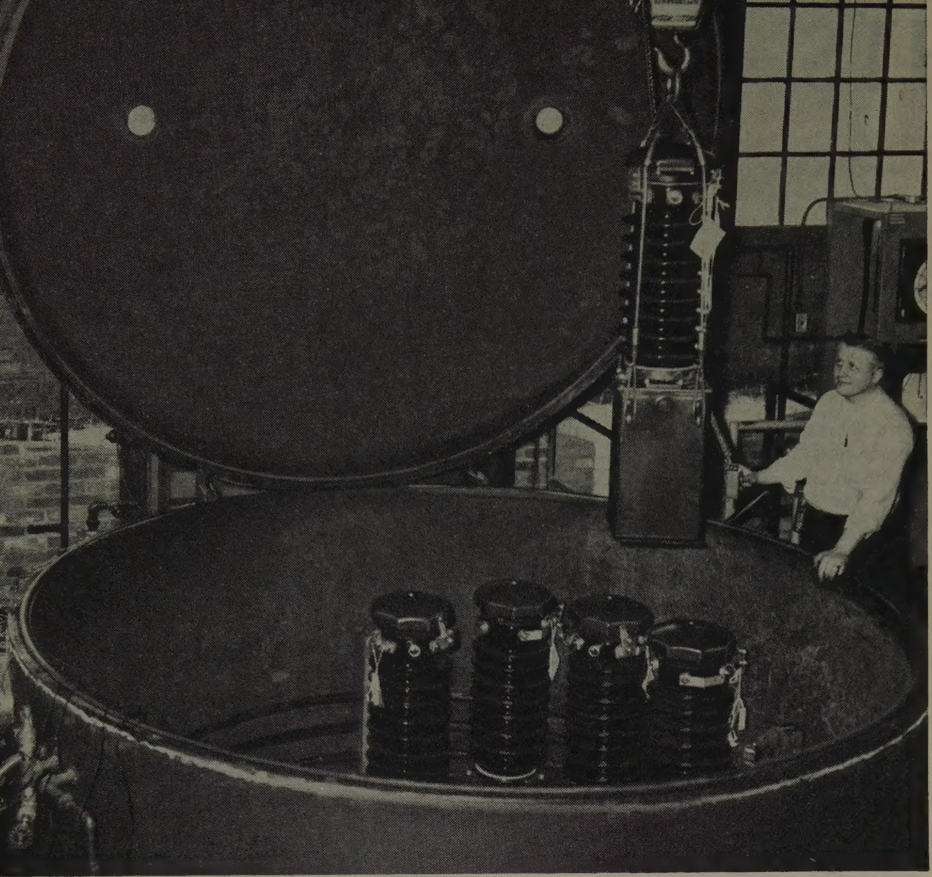
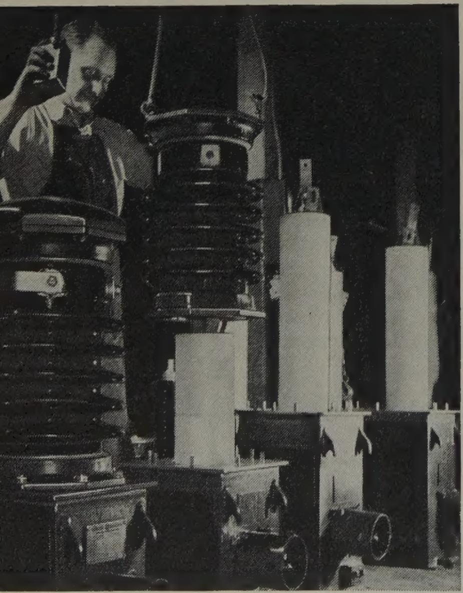


TRANSFORMERS ARE PLACED IN VACUUM TANK TO REMOVE MOISTURE FROM WINDINGS

How G.E. Builds High-voltage Instrument Transformers for Dependable Operation



DURING FINAL ASSEMBLY, bushings are fitted on base tanks, maintaining uniform pressure. Long-life nitrile rubber gaskets are the result of years of G-E research.

Built for heavy-duty service, General Electric's Type KG current transformers offer both dependable operation and high, sustained accuracy. Each manufacturing operation, each design detail contributes to sturdy construction and long life.

Core and coils are mounted in a shallow tank and coil leads extend up through a heavy insulating barrier into a porcelain housing which acts as a primary bushing.

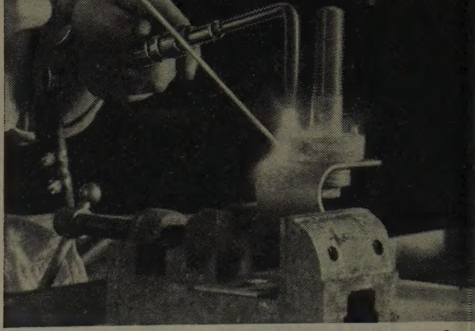
HIGH SUSTAINED ACCURACY

Exclusive features of G-E Spirakore core, for example, assure higher degree of accuracy. Another help: secondary winding is uniformly distributed around core. Transformers are suitable for accurate metering service down to five per cent of the primary current rating and for relay operation up to twenty times full-rated current.

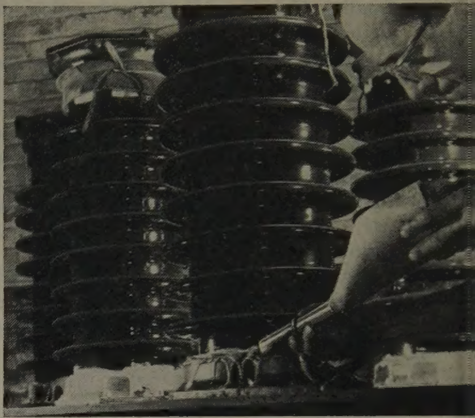
They're available in 25,000- to 69,000-volt ratings. For complete details, see your G-E representative. General Electric, Schenectady 5, New York.

GENERAL ELECTRIC

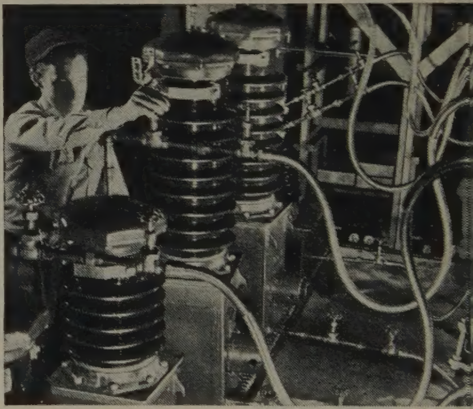
604-32



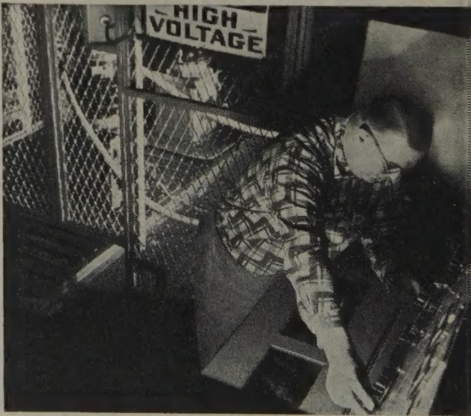
FLEXIBLE LINE TERMINALS are welded to studs. Copper straps connected to studs provide for making series and multiple connections on primary coils without opening transformer.



PORCELAIN BUSHING CEMENTED to top and bottom rings. For greatest strength, cement is steam-oven-cured and wet-process porcelain is straight in design rather than tapered.



FILLING STATION slowly injects de-aerated oil while a vacuum is held, impregnating the insulation. Previously, tank was partly filled with sand to keep oil expansion to a minimum.



TO ASSURE HIGH ACCURACY, each completed transformer receives rigid ratio and phase-angle tests which prove that it is well within ASA accuracy-standard classification.

A 10-Year Evaluation of a Job Rotation Executive Development Program

D. SARGENT

Training key executives who are "generalists" rather than specialists is a major problem of any large concern. In this article are presented the results of a job rotation program for potential executives which has been in progress at the Consolidated Edison Company of New York.

THE INTEREST THAT exists these days in the subject of executive development is impressive.

The American Management Association last fall ran a conference where five good papers were presented on this subject. Many management consulting firms seem to have given a lot of thought to this matter and appear to be in a position to advise anyone who wants to start a program. I recently looked over a beautiful brochure produced by Sears Roebuck Company on "Our Concept of Executive Development." Westinghouse Electric Corporation has put a great deal of thought in their program, which has been printed under the heading, "Leadership Through Management Development." We know Standard Oil of New Jersey and General Foods have had a program in effect for several years and I understand that the General Electric Company is making some extensive plans right now in this direction. Only this week we had a request for information on executive development and training from the State Electricity Commission of Victoria in Melbourne, Australia!

As I look back at our program, I am reminded of the definition of a democracy versus the definition of a dictatorship. A democracy is like a raft; you can't steer it, your feet are wet all the time, but the raft never sinks. The dictatorship is like a trim destroyer; it can go 40 knots right to where it is directed, but if it hits an iceberg or a rock, it can sink in 2 minutes.

At Consolidated Edison we can look back 10 years and realize that in that period some 200 management employees have spent over 500 man-years on our executive development program. Looking back, our approach to this program was certainly democratic; our feet have been wet most of the time. On the strength of an idea, without any formal plan, we arranged for a few men to exchange jobs. Then we decided to keep a record of these exchanges; then we decided maybe we ought to have a written report of the individual's performance. For some time we were satisfied with a very simple report; it boiled down to something like this: a department head to whom a management employee was assigned was asked, toward the end of his assignment: If you had a vacancy in your department, would you like to keep this man? Obviously, if the department head said "yes," that was really good. If the department head said "no," it might be because the man was not very competent to begin with, or that he was a good man but would not do for that kind of work. In any event, this one question appeared to be adequate.

After a little while, we dressed up our report, asked quite a few more questions, got them all in writing, and I think we have improved the record of reports. Early in the game we knew that some men had been assigned to jobs which probably hadn't helped them or the company, and after a number of these took place, we got busy and arranged for the sponsors, that is, the men who recommended someone for the program, to give us a list of the specific departments to which a man should be assigned, which list the man also had agreed to and usually had suggested. This appeared to eliminate the possibility that a poor assignment might slip through. Then also, early in the game, occasionally we put a man on the plan who was more of a problem than a "potential." We knew it, some of the men on the program knew it, but some, who didn't quite understand it, weren't sure of just what the score was generally, and began to wonder whether they were really considered as potential executives or whether, as far as they were concerned individually, this assignment was just the first step on the way out. This was not good practice and no one should follow it. We are not doing it now.

A few years ago, we made up a fancy chart of the whole organization, showing all the key management jobs. The name of the man in each key job and the year this individual would be retired for age was put down. Then we figured it would be a good idea if we could develop via the executive training program specific individuals as potential replacements for specific key people. It wasn't long before we came up with the answer that, with the proper training, a given man would be satisfactory in any one of a number of executive jobs—so out went the fancy chart. It was pretty, but not needed.

More recently, we became properly curious as to the answers to two fundamental questions:

1. Had the company wasted money on this program, or had the company actually secured some of the benefits it hoped it would?
2. Did the men who participated feel that they had been "spinning their wheels" or did they feel well repaid for the time they had spent "being trained?"

Essentially full text of a conference paper recommended by the AIEE Committee on Management and presented at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952.

D. S. Sargent is with the Consolidated Edison Company of New York, New York, N. Y.

We decided to find out, as best we could, what the answers were. Accordingly, each vice-president was requested to give his opinion as to every man he had sponsored on the program and as to every man who had been assigned to any one of his departments by some other vice-president. We also sent a questionnaire to every graduate. We received back, unsigned as requested, 75 per cent of these questionnaires. We asked frank questions and we certainly got frank answers. We have made no check to determine, and therefore do not know, who filled in the questionnaire and who did not return it.

The results of these two group opinions are what I am going to cover. Before giving you the results of the evaluation, I want to discuss briefly:

1. A history of our executive development program.
2. The objectives of our plan as we have visualized them, both to the company and to the participants.
3. Our method of operation.
4. Some of the undisputed beneficial results which we know have come because of the program.

HISTORY OF CONSOLIDATED EDISON'S PROGRAM

The present Consolidated Edison Company with almost 30,000 employees is now the largest privately owned, business-managed utility of its kind in the world. We supply the greatest metropolis in the world with three services; electricity, gas, and steam. The present company, as its name implies, is a consolidation of many independent utility companies. Our present management development program was proved very effective during the years when these companies were being merged together as one consolidated unit. We have many major functions, such as: engineering, production, operation, construction, sales, customer relations, purchasing, finance, industrial relations, and public relations. Our present program is, perhaps, 90 per cent job rotation. We do not hesitate to transfer trainees between any of the above major functions.

Our executive development program really had its inception in 1933, when the job rotation idea was first used by some of the separate units as a part of management development. With retirement compulsory at age 65 for males, management recognized the need for early development of men for potential management positions. To avoid developing mere specialists and to provide a strong management team, flexible enough to keep up with a rapidly changing organization, the job rotation plan was developed. It is of interest to note here that the plan was conceived, instituted, and maintained first by the line organization. The program was started originally by a small group of department heads who represented the several engineering and operating departments and who functioned together as a committee. This group arranged to interchange, among their own departments, a few supervisory employees where the need for broader experience was indicated. During this early period, we learned that knowledge of the job, alone, is less important in upper supervisory and management positions than an ability to carry out company policies. This interchange also established the means for determining an individual's ability to handle management problems of broad scope. Similarly, endorsement by more than one member of top management is always reassuring.

Then in 1943, at a time when many of our key men were away on war-time or military leaves of absence, we took a close look at our organization and found that we were faced with the situation wherein many of our executives who had grown up with the system and who were familiar with its many functions, were nearing retirement age. Back of this group were our junior administrative people, most of whom had been brought up as specialists. For the most part, these individuals had only a sketchy knowledge of the many activities of the merged companies and had not been given an opportunity to broaden their experience and their knowledge of the system's operations. Certainly these people would be under a serious handicap if asked to step into a higher management position requiring ability to handle problems of a system that includes electric, gas, and steam operations, each with its many functions. In addition to the replacement problem, there was also a real need for more management employees with a broader system knowledge of these various functions.

OBJECTIVES OF THE PLAN

Our first objective was to build up a reserve of qualified people, with well rounded knowledge and experience, to fill by horizontal transfer or by promotion, when needed, our key management positions.

We didn't tell a man going on the program that he would be a vice-president in 5 or 10 years; we did say substantially that after he had the executive development training, he would stand a much better chance of being considered for a top job, than if he did not have the training. It was one of those situations where we felt he could not lose, but he might not win.

Our second objective—and I believe it was stated very simply to a man who was going on the program—was to give these men a broad experience in different phases of the company's work. With this broader experience, they should become more effective in their old job, if they returned to it, or in any job they might receive.

Our third objective was very definitely a desire to develop "generalists"; that is, men who think from an over-all company viewpoint, rather than from a "specialist's" or "my department" viewpoint. In addition, we really hoped that the team work and morale of the management group would be improved generally.

OUR METHOD OF OPERATION

The president of our company sponsored our new executive development program in 1943. Facetiously referred to as the "merry-go-round," it is alphabetically called the "E.D.P." A senior vice-president was asked to direct its activities and an executive development committee composed of department heads, with the directing vice-president as chairman, was selected to administer the program. This committee meets at least three times each year to make new appointments, arrange transfers, discuss progress of individuals, and recommend pay increases, and so forth.

Department heads are asked to submit the names of promising men as prospective candidates for training. Because of the large number of experienced long-service employees it was decided at first to limit consideration of candidates to those most promising persons between 40 and 50 years of age. Recently the trend has been toward younger age groups.

The qualifications, experience, and personality of each of the recommended individuals are carefully reviewed by the committee and the most likely prospects accepted for assignment to the program.

Having previously agreed upon certain requirements and specifications for key management positions, it is possible for the committee to plan and schedule each candidate's training by comparing his qualifications and experience with the requirements of certain management positions. As a rule, the maximum period of time a candidate is assigned to the program is 5 years, during which period he is delegated to four or five departments. This time may vary, depending on the circumstances. During his stay with each department the candidate is usually assigned by the department head to spend some time in each of the departmental bureaus where he learns by carrying responsibility in a line or staff job in the bureau's activities.

We knew that complete co-operation in our training program would not be possible unless everyone was informed about it. The best medium to accomplish this was our employee magazine "Around the System." So, in August 1943, "Around the System" carried a 2-page announcement by our president, outlining the plan and its objectives. Subsequent issues have carried stories about the executive development program, telling of new appointments, changed assignments, and any items of interest about the program that might be currently pertinent.

Generally, we attempt to operate the program as informally as possible. The keynote of our plan is flexibility. Trainees do not follow any fixed schedule of assignments.

The trainees also attend and in many cases conduct company industrial relations meetings where open discussions are held on labor-management problems. In addition they also cover industry meetings conducted by such organizations as the Edison Electric Institute, American Gas Association, National Industrial Conference Board, American Management Association, and so forth. News letters are issued from time to time to inform the group about significant matters and to report assignments of E.D.P. members.

A significant feature of our E.D.P. is the department head's responsibility for his protégé. He must first "sell" the employee to the executive development committee. Once the man has been appointed to the program, his sponsor is responsible for following through with the employee, even to the extent of following his pay increase progress. The department head is expected to talk with his man from time to time and counsel him on future moves, talk about his desires, and get his ideas about his E.D.P. experiences to date. If the employee is having any difficulty in any of his assignments, his sponsor is expected to help him. As the employee progresses in his E.D.P. assignments, we find that he is more apt to want advice about his future moves.

Record keeping is held to a minimum. An "Executive Development Program Record" is kept to show the usual employment record information, a record of assignments and payroll changes while the employee is a member of E.D.P., and a summary of answers to three key questions on the "Annual Personnel Rating" form. This form was developed by the committee and has been progressively improved. Printed on both sides, this $8^1/_2$ by 11-inch form is both a rating and an appraisal record. Department heads are required to fill out one of these forms for each E.D.P. member assigned to his department.

Since the beginning of the E.D.P. in 1943, 220 individuals have participated, 200 have "graduated" and 20 are presently assigned.

The following breakdown of our 200 graduates shows that all levels of management, including officers of the company, are represented in our "alumni."

Controller	1
Assistant to President	1
Assistant Vice-President	1
Department Heads	13
Assistant Department Heads	12
Bureau Heads	29
General Superintendents or Equivalents	43
Engineers	49
Other Professionals	51
	200

SOME SPECIFIC RESULTS THAT ARE GOOD

1. During the past several years E.D.P. men have received on a ratio basis five promotions to one received by a man on the monthly roll who had not been on the E.D.P. program.

2. An analysis of the annual amount of increase for E.D.P. men, against other men on the monthly roll not on the E.D.P. program, reveals the ratio of total amount of increase for the E.D.P. men is approximately 50 per cent more than that received by the non-E.D.P. men.

We recognize, of course, that in the vast majority of cases the E.D.P. men were picked because they were outstanding and promising to begin with. I cannot say that some or many would not have received the promotion if they had not been on E.D.P. I think I can say that these men have moved faster and received higher amounts of increases because they did have the E.D.P. experience.

3. I want to mention here one other most important and satisfying result. A few years back the a-c boys in the old United Company were considered rather cocky competitors by the older d-c boys in the old New York Edison Company. Both the a-c and the d-c boys had nothing to do with the gas boys of Consolidated Gas, who knew they owned the place anyway. We had walls around us that just were not scaled.

We used to hear "Oh, we can't do it that way, our conditions are different." Or, "that may be all right for you, but it wouldn't work out here." Or again, "I don't worry about what happens in that department, I'm going to do it my way." Or still again, "You don't understand our problem," and so on and on.

If the E.D.P. has done nothing else, it has, over the years, as an inescapable result of key people being moved around, broken down all those jealous and selfish walls that existed between companies, between vice-presidents, and literally between departments. Further than this, in the process of moving around, the E.D.P. people get to know, personally, many more of their contemporaries in management—a decided advantage and a desirable objective. I don't think anyone could ask for a more co-operative, considerate, understanding of what's best for the company attitude than we have today. I can't price it out, but it's worth a lot.

4. One other result which is quite gratifying: without a shadow of doubt, 99 per cent of the men when they went on the program expected to return to their old jobs, yet 57, or over one-quarter, of the graduates have actually, via the E.D.P. experience, found jobs that they liked better, in which they could go further, and in which the company benefited correspondingly.

5. The following are a few of the cases selected from a considerable list, all of whom management is really pleased with, because today they are undoubtedly available for top executive replacements. In addition, they are each doing an important job better because of the E.D.P.

Mr. A. Background, Electrical Engineering Department. Length of service at the time of appointment was 16 years. Position at time of appointment on program was division engineer, Electrical Engineering Department. His assignments were as follows: one year, assistant general superintendent, Underground Bureau of the Outside Plant Construction Department. One year, assistant engineer, Electric Production Department. Third Year, general sales manager, Westchester Lighting Company, a subsidiary company. Fourth year, engineer, Distribution Division, Service Department of the same subsidiary. Fifth year, returned to Consolidated Edison as assistant outside plant engineer, Outside Plant Bureau, Electrical Engineering Department. This completed his tour of assignments of the program. Since then he was promoted to the position of outside plant engineer, Outside Plant Bureau, Electrical Engineering Department, and later to planning engineer of the Planning Bureau, System Engineering Department. This man doesn't think only in terms of "my department."

Mr. B. Background, Distribution Engineering Department. Length of service at time of appointment to the program was 16 years. Position at the time of his assignment was division engineer, Outside Plant Bureau, Electrical Engineering Department. His first position was electric superintendent, Electrical Division of the Electric Production Department, Hudson Avenue Station. His next assignment was division engineer of the Planning Bureau of the System Engineering Department. His final and present assignment is assistant inside plant engineer, Inside Plant Bureau of the Electrical Engineering Department. This man is no longer a "specialist."

Mr. C. Background, Research and Test Departments. Length of service at time of appointment to the program was 18 years. His position at time of appointment was division engineer, Distribution Engineering Bureau, Electrical Engineering Department. His first assignment, division engineer, Electrical Construction Bureau, Station Construction and Shops Department. He was on a leave of absence for 3 years on a government project during the war in which he obtained valuable experience in construction and operating work. His next assignment was assistant manager, System Operation Department. His next assignment was general superintendent of production, Hudson Avenue Station, Electric Production Department. Since completing his tour of assignments on the program he has been promoted to superintendent, Electrical Production Department, General Superintendent, Gas Production Department, and later to manager of the System Operation Department. This man certainly thinks in terms of the company's needs.

Mr. D. Background, Electrical Engineering Department. Length of service at time of appointment to the program was 20 years. His position at the time of appointment was division engineer, Test Bureau, Electrical Engineering Department. His first assignment was assistant engineer, Hudson Avenue Station Bureau of Electric Production Department. His next assignment was superintendent's assistant, Gas Mains and Subway Bureau, Outside Plant Construction Department. His next and final assignment was distribution engineer, Transmission and Distribution Bureau of the Electrical Engineering Department. Since completing his tour of assignments on the program he has been promoted to distribution engineer of the Transmission and Distribution Bureau, Electrical Engineering Department. This man is another man who doesn't permit any invisible walls to grow up between departments.

Mr. E. Background, Transmission and Distribution Department. Length of service at time of appointment was 24 years. Position at the time of appointment to the program was superintendent, Substation and Maintenance Bureau, Substation Operating Department. His first assignment to the program was as assistant general superintendent in the Overhead Bureau of the Electrical Distribution Construction Department. His second assignment was assistant chief engineer of the Distribution Division of the Outside Plant Construction and Service Department of our Westchester subsidiary. His third assignment was assitant personnel director of the Personnel Department. His final assignment on the program was general superintendent in the Outside Plant Construction Department. He was later promoted to manager of the Outside Plant Construction Department. In addition to the usual assignments this man spent a year with us in personnel. He helped us and I hope we helped him.

I know that these examples are only typical of the type of training we are providing to develop executives in our organization.

RESULTS OF THE SURVEY

WE GAVE EACH vice-president a complete list of the employees whom he sponsored for the executive development program and of all other employees sponsored by other vice-presidents with whom they had any direct organizational responsibility. Table I shows their answers to our first question.

Table I. Would You Have Chosen These Employees for E.D.P. If You Had a Chance to Do It Over Again?

	Yes (Per Cent)	No (Per Cent)
Group 1 (Sponsoring vice-president to same vice-president)	79	21 (8*)
Group 2 (Sponsoring vice-president to other vice-president, other vice-president said)	78 (4*)	22 (4*, 4**)
Group 3 (Sponsoring vice-president to other vice-president, sponsoring vice-president said)	67 (4*)	33
Group 4 (Still active, sponsoring vice-president said)	84	16
Group 5 (Inactive, left company for military service, etc., sponsoring vice-president said)	77 (8*)	23 (15*)

* Placed on E.D.P. as an expedient, that is, to make a vacancy for other movement or as a problem case.

** Believe he would have done better if given different assignments or different timing.

These figures speak for themselves and each of the five groups shows a reasonably high satisfactory result.

Table II shows the answers to the next question we gave the vice-presidents, which was: "In the cases of those employees to whom you answered yes in question 1, to what extent were you satisfied with the results of the E.D.P. experience?"

Table II. Cases of Those Employees Whom the Management Would Have Chosen Again for E.D.P.

	Highly Satisfied With Results (Per Cent)	Well Satisfied With Results (Per Cent)	Results Just Satisfactory (Per Cent)
Group 1 (Sponsoring vice-president to same vice-president)	44	47	9
Group 2 (Sponsoring vice-president to other vice-president, other vice-president said)	43	52 (2*)	5
Group 3 (Sponsoring vice-president to other vice-president, sponsoring vice-president said)	44	41 (2*)	15
Group 4 (Still active, sponsoring vice-president said)	43	57	0
Group 5 (Inactive, left company for military service, etc., sponsoring vice-president said)	40	40	20 (10*)

* Placed in E.D.P. as an expedient, that is, to make a vacancy for other movement, or as a problem case.

RESULTS OF SURVEY OF E.D.P. GRADUATES

Our first question on a questionnaire to E.D.P. graduates with the resulting replies are shown in Table III.

Table III. With Your Present Knowledge of the E.D.P. and If You Could Do It Over Again Would You Repeat the Assignment or Would You Decline?

	Employees	Per Cent
I would do it over again	136	91
I would pass it up	14	9
No answer	1	

I think this, without question, is a very high endorsement of the E.D.P., in that of the 150 men who actually answered, 91 per cent felt that they got enough out of it so they would repeat the experience. Approximately 50 individuals out of the 200 to whom it was sent did not return the questionnaire.

Then we asked, "How do you evaluate the results as far as you are personally concerned?" This is shown in Table IV.

Table IV. How Did the E.D.P. Employees Evaluate the Results as Far as They Were Personally Concerned?

	Employees	Per Cent
Highly satisfied with results	42	28
Well satisfied with results	67	45
Just fairly satisfied with results	40	27
No answer	2	

Again, these figures speak for themselves. Of course, we might like to see more than the 28 per cent who answered the questionnaire as highly satisfied, but I think in all fairness, we can assume that the first two categories, which total 73 per cent, are well worth while.

Table V shows how E.D.P. employees answered four criticisms which have been made from time to time.

Obviously, we are not particularly proud of the reply to question 1. I hope that quite a few of the men who answered "True" graduated from the program several years ago and that the conditions have been improved as of now. I think I am justified in assuming that this is the case, because replies from 14 people who are now on the E.D.P. indicate that only 1 out of the 14 feels that he is not being given enough work to do.

In many ways, having seen the reply to the previous question, I would expect a similar or higher reply to question 2. The reason for these replies is borne out by some of the comments that were made as remarks on the individual questionnaires. I think that all we can say on this item is that this matter will be given more and more attention in the future, and will be fixed if humanly possible.

We admit very cheerfully that the reply to question 3 is a 20 per cent reflection on the way we would have liked to have seen the program operate. I am quite sure that the 20 per cent who answered "True" to this question have been graduated for some period because, again, none of the current members of the Executive Development Program answered this statement as "True."

In question 4 the 40 per cent factor is the unfavorable answer. This is a direct reflection on a number of sponsors who, for one reason or another, delayed getting in touch with the man they sponsored, and simply failed to have a few short conversations as to how the man was getting along, and just did not keep in touch with him. This matter, of course, is one which will be worked on to make sure that the condition does not continue.

It is of interest generally that in Table IV, 27 per cent of the men reported that they were just fairly satisfied with the results of their assignments on the E.D.P. As we further analyze this 27 per cent, we do find that a higher percentage of them have reported, as we see it, unfavorably, in the four criticisms just covered. This, we might expect.

Our next question related to the various assignments given to E.D.P. people, and the results are shown in Table VI.

Table V. The E.D.P. Employee Opinion on Criticisms

	True		False	
	Employees	Per Cent	Employees	Per Cent
1. During my assignment on the E.D.P., I was not given enough work to do. No answer—9	46	32	96	68
2. During my assignment on Executive Development Program, I was not given as much responsibility as should have been given with the assignment. No answer—5	59	40	87	60
3. During my time on Executive Development Program, I felt more or less lost and somewhat like the man without a country. No answer—5	29	20	117	80
4. During my assignment my sponsor showed a reasonably frequent and helpful interest in how I was getting along. No answer—7	86	60	58	40

Table VI. E.D.P. Employee Reports After Having Considered the Assignments Which They Were Given

	Employees	Per Cent
1. Other assignments would have been more profitable to them and the company in their development	51	39
2. Assignments were satisfactory and no change suggested	81	61
No answer	19	

Here again, 39 per cent of the men felt that different assignments would have been more helpful. I know that in some of these cases, different assignments probably could have been worked out but there will certainly be cases, as long as we have a program, where a particular assignment is desired by a man and because his sponsor does not necessarily believe it essential, he may not get it. Some per cent of graduates 10 years from now would probably answer this question, "Yes" again. I do think, however, that the whole assignment picture has been considerably improved in the last few years by requiring each sponsor to submit to the vice-president who operates the E.D.P. the assignments which he and the man both agree are most desirable for him individually.

The last question, in two parts, was directed toward the duration of individual assignments while on the E.D.P. Each assignment on the program averages about 1 year. In the first part of the question, E.D.P. employees were asked what they thought the most suitable period would be. These results are shown in Table VII, indicating that a substantial majority, 83 per cent, believe that the 1-year period is about right.

The second part of the last question was directed at the total time spent in the program, and the results are shown in Table VIII. The average time on the program of the men who answered this question is 3.2 years. The men who said that their time on the program was adequate actually averaged 3.6 years. The men who said it was not adequate actually averaged 2.3 years. In a similar manner, the men who said that a longer period on the program would have been helpful averaged 2.4 years; the men who said that a longer period on the program would not have been helpful averaged 3.7 years.

Table VII. Length of Time Thought Suitable for Each Assignment

	Employees	Per Cent
Six months	19	13
Year and a half	6	4
Leave as is	117	83
No answer	9	

Table VIII. Adequacy of Total Time Spent on Program

	Employees	Per Cent	Average Number of Years on E.D.P
Was the time you were on the program adequate?			
Yes	85	64	3.6
No	48	36	2.3
No answer	18		
Would a longer period on the program have been helpful to you?			
Yes	59	42	2.4
No	82	58	3.7
No answer	10		

We have made an analysis, of course, of the comments which were made on the various questionnaires that were returned. These can be summarized as follows:

16 comments criticized the method of assignment as experienced by the individual.

15 comments criticized the sponsors' neglect and lack of interest.

17 comments were constructive suggestions which could be considered, if adopted, as improvements in method of procedure.

7 comments were simply complimentary.

That just about completes the results of our survey. We honestly believe that the E.D.P. has done a creditable job for us. Based on our estimated needs, we feel we're in good shape as far as top job replacements are concerned. Based on our records and experience, we anticipate that in the course of the next 10 years, we will lose through age and disability retirement some 61 men who are now in top management jobs. To balance off this loss, we have approximately 100 men under 50 years of age whom we consider available as top management replacements. About two-thirds of this group are E.D.P. graduates. In addition, we have other really competent people who are over 50 right now and who are also E.D.P. graduates, but I haven't included them in the 100, because, frankly, those who are over 55 have normally but 10 years to go to retirement and we are looking beyond 10 years.

It would be proper, I believe, in conclusion, to tell you what and how we feel as to the future of the E.D.P. Right now, in our organization, it is relatively small, with only 20 men actively on the program. We anticipate that the number will gradually decrease until a new crop of young people begin to qualify, probably within the next 5 or 10 years. We all agree, however, that the program will be kept going, even if we get down to two active participants, and that the company would be the loser if we let it drop.

Predicting Magnetic Amplifier Control Curves

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THE CONTROL CURRENT flowing in a self-saturated magnetic amplifier supplies the magnetomotive force to maintain the specified bias flux density in the core. To predict the output obtained for a given control current the magnetic properties of the core material must be known.

If this bias flux density is known, the magnetic amplifier may be treated like a thyratron. When the instantaneous flux density in the core is between the bias density and the firing flux density at the knee of the hysteresis loop, all of the supply voltage appears across the reactor and no output is obtained. As soon as the core flux density exceeds this latter value, the core permeability drops to a very low value, and practically all of the supply voltage appears across the load for the remainder of the half-cycle.

Such an analysis was developed by W. J. Dornhoefer[1] for circuits with high control winding impedance, to prevent the flow of alternating currents. The method described herein has been applied successfully to half-wave and full-wave circuits of this type.

This analysis is based on the assumptions of: 1. perfect rectifiers; and 2. core materials having very rectangular hysteresis loops. The first assumption is not met in practice, but its use permits the study of the effects of the magnetic core by themselves—the first step in the complete analysis of the magnetic amplifier.

The relationship between the control current and bias flux density cannot be obtained from the d-c hysteresis loop. Eddy currents flowing in the core produce losses which must be supplied from the reactor windings. Because of the low d-c coercive force of the rectangular hysteresis loop materials used in high-grade magnetic amplifiers, the additional magnetizing force required to supply these losses is of great significance. The coercive force at 60 cycles per second of 0.010-inch-thick laminations of Deltamax is $2^{1}/_{2}$ times that under d-c excitation. Figure 1 shows the comparison between the d-c and dynamic hysteresis loop for this material.

It has been found that the use of the demagnetizing quadrant of the dynamic major hysteresis loop obtained at the operating frequency also yields unsatisfactory correlation with experimental results.

There is only one way in which the true relationship between the control current and the bias flux density may be obtained. By means of an a-c and a d-c winding on a sample of the core material, the minor dynamic hysteresis loops are obtained for various d-c magnetizing forces. The locus of the bottom tips of these minor loops is plotted against the applied magnetizing force. This has been called the control magnetization curve. This curve is plotted on Figure 1 along with the hysteresis loops.

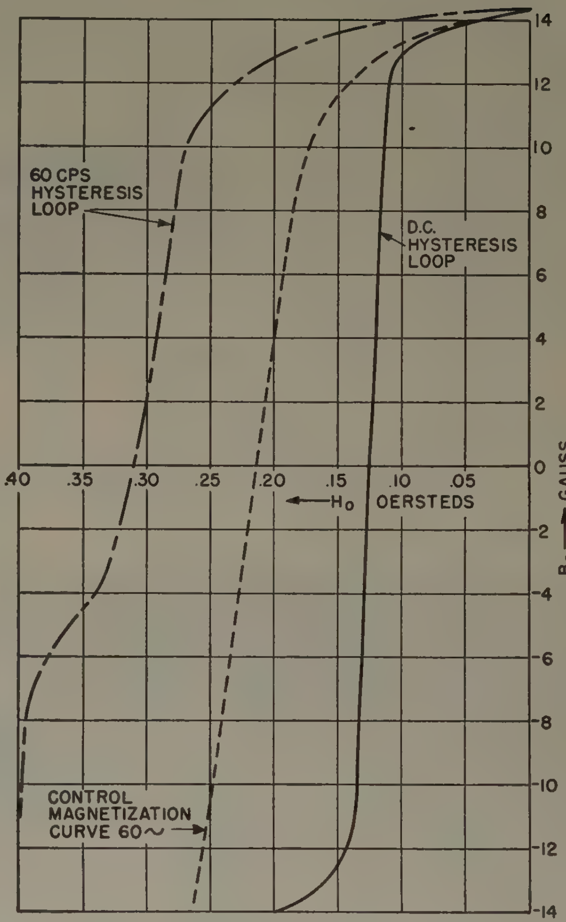

Figure 1. Control magnetization curve in relation to d-c and dynamic hysteresis loops for 0.010-inch-thick Deltamax

The relationship between flux density and magnetizing force thus obtained is used to determine the residual flux density in the core for any value of control current. Control characteristics computed in this manner yield excellent correlation with experimental results.

For this curve to be of most value in designing magnetic amplifiers, it should be taken on the actual core to be used. This refers to material composition and thickness, anneal, shape, and frequency. A variation in any of these factors will change the relationship between the flux density and magnetizing force and introduce errors in the calculations. This may appear as a large task, but it is done for hysteresis loops or core loss curves used in transformer design, and this curve may be considered as equally important to the magnetic amplifier designer.

REFERENCE

1. Self-Saturation in Magnetic Amplifiers, W. J. Dornhoefer. AIEE *Transactions* volume 68, part II, 1949, pages 835-50.

Digest of paper 51-387, "Predetermination of Control Characteristics of Half-Wave Self-Saturated Magnetic Amplifiers," recommended by the AIEE Committee on Magnetic Amplifiers and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, part II, 1951.

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Very-High-Frequency Radio Communication in Train Operation

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Railroad operations require on-the-spot communication facilities, for which the telegraph is often inadequate. Radio communication on the very high frequencies fills the gap as it provides the means by which a dispatcher can converse with the crew of a speeding train miles distant from his office.

IT IS A familiar fact that the railroads of the United States utilize a vast system of wire communications. Generally each railroad owns, operates, and maintains its communications plant. This is the case on the Erie Railroad, where today the telephone is in almost universal use in the dispatching of trains and divisional communications. Modern carrier provides increased circuit capacity for system-wide long-distance telephone and teletype networks. Over the teletype network is handled the heavy volume of communications concerning specific make-up of trains en route between terminal yards, the tracing and reconsignment of freight traffic, messages concerning passenger traffic, and general administration. Western Union and Bell-leased wire teletype circuits and teletypewriter exchange service connect Erie's sales agencies in the United States and in Canada as direct tributaries to the on-line net.

Wire-line communications alone, however, leave a gap in a railroad's communications system—that between moving trains and fixed points along its main or branch lines, or in its yards and terminals. Efforts to bridge this gap date back to the early spark and crystal days, through the American Association of Railroads–manufacturer development of electronic systems using long, then short-wave radio and induction methods. It was not until after the close of World War II, during which substantial advances were made in very-high-frequency (VHF) techniques, equipment, and tubes, that practicable radio and improved induction systems were developed for use in train communication.

Figure 1. Instructions to tugs in New York Harbor are sent by radiotelephone from the Erie's boat dispatcher in Jersey City, thus speeding the lighterage service

In 1945 and 1946 the Erie was one of the first railroads to conduct tests along its right-of-way of inductive carrier and both amplitude-modulated and frequency-modulated VHF equipment. The New York Harbor radio service was established in February 1947, between the boat dispatcher in Jersey City and the lighterage tugs; see Figure 1. It is providing added safety and increased dependability in marine operation through immediate issuance of orders to tugs, assuring "on time delivery" of defense, perishable, and other domestic and export freight.

Also in February 1947, arrangements were made with a manufacturer to conduct a prolonged test to determine the most practicable type of train communication equipment and circuits available for use in main line operation.

After more than a year of experimentation through rolling terrain on the 115-mile Kent Division between Marion and Kent, Ohio, the Erie-Farnsworth main line system was developed to meet requirements in providing added safety, efficiency, and dependability in railroad operation. See Figure 2. In July 1948, the newly developed system was placed in service over three operating divisions from Marion, Ohio, to Salamanca, N. Y., providing a radio coverage of 360 miles of main line trackage. Radio equipment was installed in nine 4-unit freight diesels, seven 3-unit passenger diesels, and 15 cabooses. In the locomotives, the cabs at each end were radio-equipped individually for greater safety and to insure availability of radio when any one of the multiunit diesels was split into smaller units. A total of 47 mobile stations and 15 wayside base stations were equipped.

The head cab section of a 4-unit 6,000-horsepower freight diesel is shown in Figure 3. The $11^1/_2$-inch "firecracker" antenna can be seen on the roof just forward of the horns. The press-to-talk handset, which is corded to a control panel mounted in the cab, is readily accessible to the firemen or the engineer, as shown in Figure 4. A loudspeaker enables them to hear all calls or communications within

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Essentially full text of conference paper recommended by the AIEE Committee on Radio Communication Systems and presented at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951.

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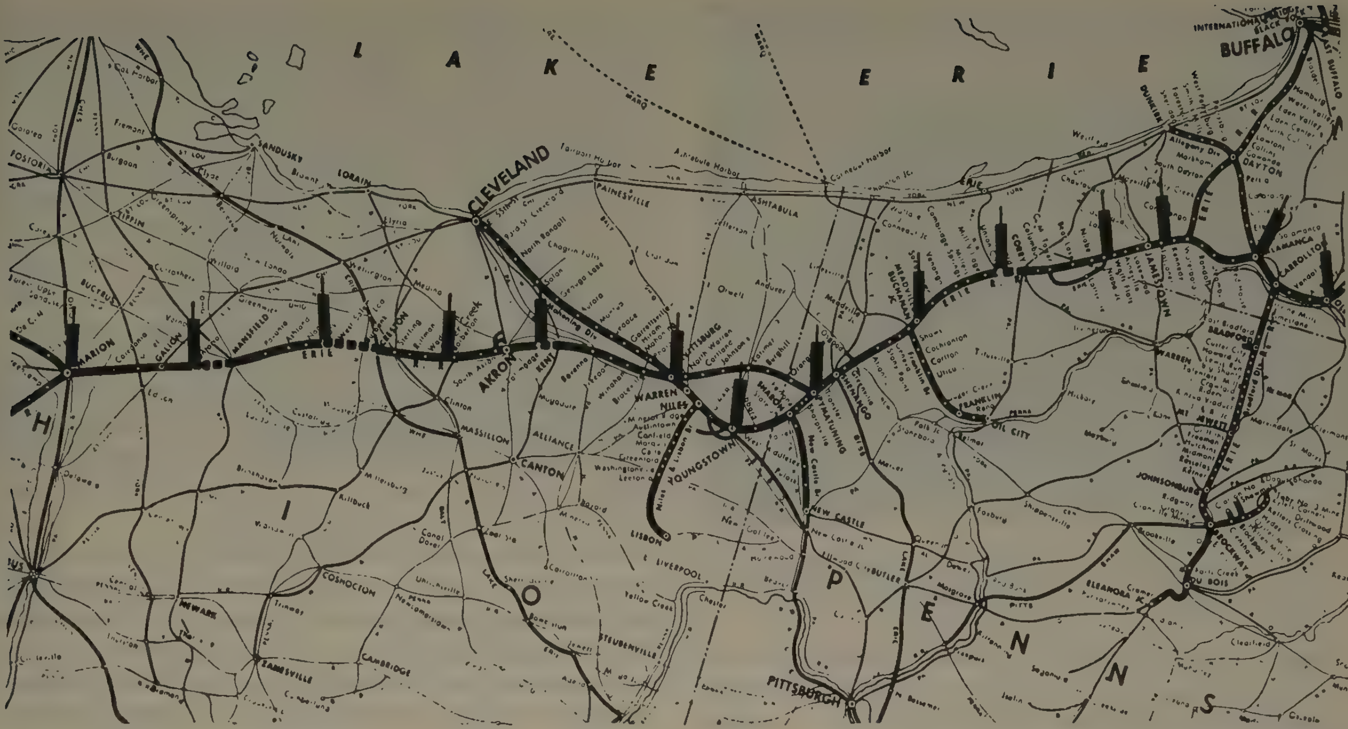


Figure 2 (above). In July 1948, radio-communication service was established over the Erie lines from Marion, Ohio, to Salamanca, N. Y., a distance of 360 miles

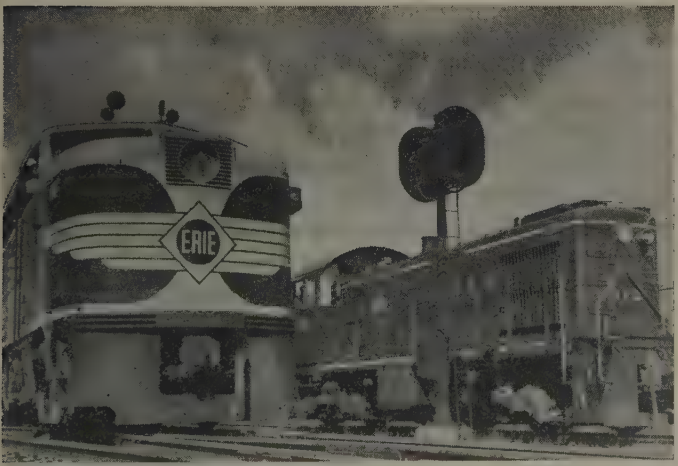
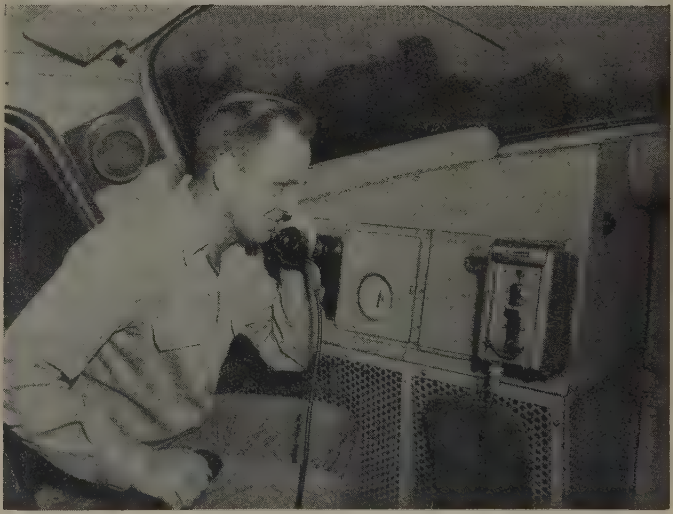
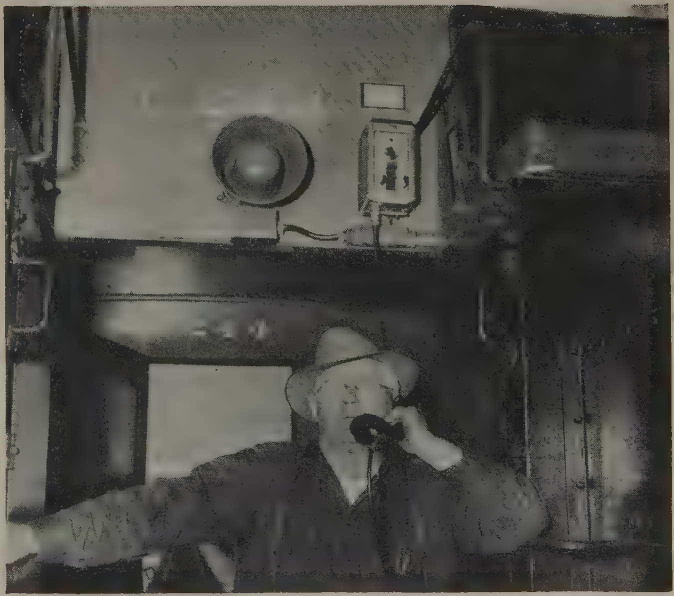


Figure 3 (above). The $11^1/_2$-inch "firecracker" antenna can be seen between the two horns on top of the diesel's cab and on the top of the shifting locomotive's cab

Figure 4 (center right). The radio handset in the locomotive cab is accessible to both the fireman and the engineer

Figure 5 (lower right). Radio communication between the engineer in the locomotive and trainmen in the caboose facilitates freight train operations. This is a caboose installation





range. Direct current at 75 volts is wired to a converter which provides 117 volts a-c. This connects to a power-supply unit furnishing heater and plate voltages used in the transmitter and receiver. These three units and the converter are housed in the nose of the diesel.

In the caboose at the rear end of freight trains and

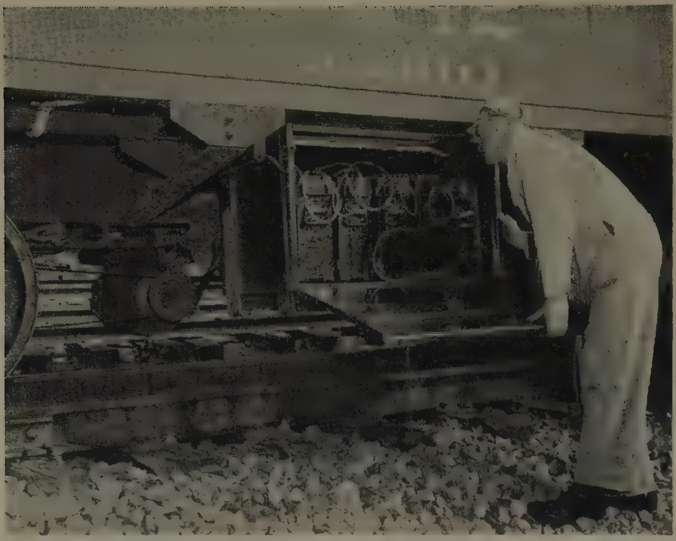


Figure 6. An axle-driven generator charges the storage-battery power supply for the radio equipment in the caboose

generally a mile or more from the locomotive, the same radio components are used, as shown in Figure 5. The antenna is mounted on the roof of the cupola. The loudspeaker and control units are mounted inside, with the press-to-talk handset within easy reach of the crew either from the floor or the cupola from which the entire train may be seen while en route. The converter is in a locker and the radio and power-supply units are housed beneath one of the floor-level seats.

Normally, there is no power source in a caboose. Therefore, an axle-driven generator is mounted underneath, which charges the 32-volt 240-ampere-hour nickel-iron-alkaline storage battery, both shown in Figure 6. The battery connects through a voltage regulator inside the caboose to the 32-volt d-c 117-volt a-c converter.

At wayside base stations the conventional antenna support consists of a 70- to 80-foot wooden pole, with or without topmast. The coaxial cable is extended inside to wall-racks holding the lightweight, low-powered transmitter, receiver, power, and control units. The top three units are identical and interchangeable with those used on the diesels and cabooses. On the desk is the base station control console enclosing the loudspeaker. The push-to-talk button is in the grip of the handset. See Figures 7 and 8.

The extension of the main line system eastward from Salamanca to the terminus on the Hudson River at Jersey City, N. J., and New York City was started early in 1949 and was placed in service early in 1950. With the extension of the system from Marion, Ohio, to Chicago, Ill., which was completed in September, radio-equipped trains are now in continuous communication with the nearest of 60 wayside radio stations as they progress along the main line from New York to Chicago. By the end of this year a total of 214 diesel freight and passenger "A" units and 68 cabooses and other mobile units will be radio-equipped.

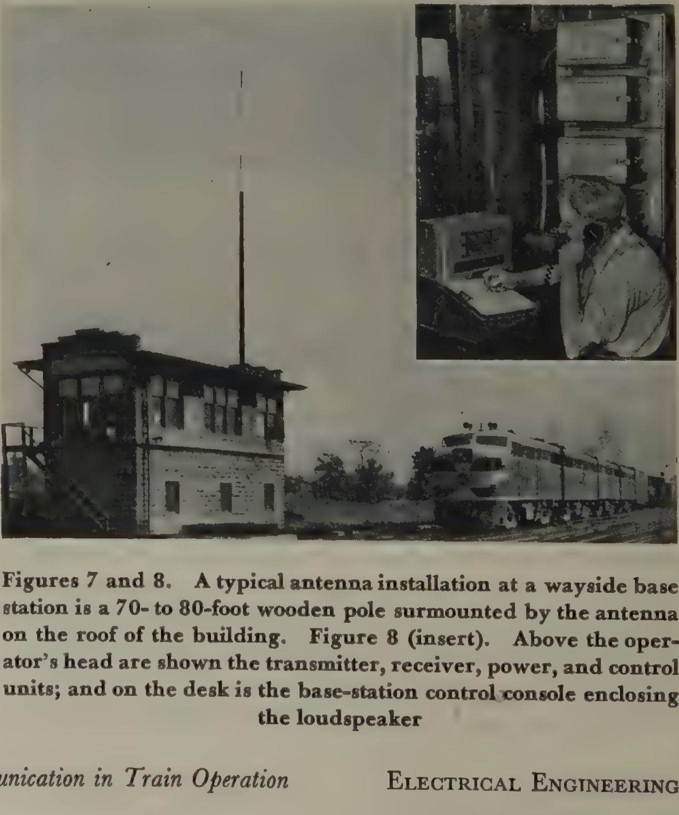
In addition to the New York Harbor lighterage service, the yards at 51st Street, Chicago, Marion, Ohio, and Jamestown, N. Y., are radio-equipped and by the end of 1951 yards at Buffalo, N. Y., Youngstown, Ohio, and Sharon, Pa., will be equipped, providing added safety and increased dependability in these marine, classification, industrial switching, and transfer operations. The total radio installations in yard and terminal service then will include 6 base stations and 73 mobile stations.

The Erie Railroad extends for 987 miles from Chicago to Jersey City, N. J., with ferries to New York and lighterage service throughout the entire New York Harbor area. The principal branches extend to Scranton, Pa., Rochester and Buffalo, N. Y., and Cleveland and Cincinnati, Ohio. It operates through territory with intervening land elevations and high structures in industrial areas which presented many propagation problems at the radio frequency normally used. The mountainous and rolling country extends westward from Jersey City for more than 700 miles to Marion, Ohio; west of Marion, through Ohio, Indiana, and a part of Illinois, it is flat prairieland.

The 4-way main line radiotelephone system provides communications between (1) locomotive and caboose; (2) trains and wayside base stations; (3) trains within range of each other; and (4) adjacent wayside base stations.

All base and mobile stations operate with a radiated power of 15 to 20 watts normally on "A" band at 160.05 megacycles. The mobile units also utilize a "B" band at 159.87 megacycles by means of which they may communicate between locomotive and caboose or between trains if the "A" band is occupied within range.

In the first of Erie's 4-way usage, between locomotive and caboose, these two units in a train are frequently more than a mile apart. Without radio, the crew in the caboose is unable to get a signal to the engineer for various reasons, and in case of "hot-boxes," to avoid burning off a journal, the air valve is opened by the crew in the caboose causing a sudden application of the brakes. This frequently resulted in broken drawbars, damaged knuckles, equipment, or lading, and possible derailment, track damage, and personal



Figures 7 and 8. A typical antenna installation at a wayside base station is a 70- to 80-foot wooden pole surmounted by the antenna on the roof of the building. Figure 8 (insert). Above the operator's head are shown the transmitter, receiver, power, and control units; and on the desk is the base-station control console enclosing the loudspeaker

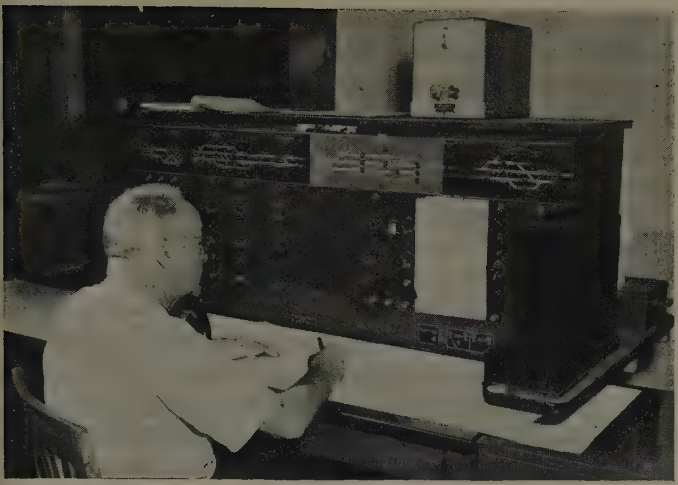


Figure 9. On top of the dispatcher's code control board is the radio control unit

injury. A crew member in any event must walk the entire length of the train in fair or foul weather to discuss and determine the plan of action with the engineer. In many cases, particularly in mountainous areas, several men are necessary along the train to relay hand or light signals.

Radio now enables caboose and locomotive crews to communicate immediately regarding any irregularities, such as hot-boxes, shifted loads, and so forth. The engineer can make a normal speed reduction or stop and action to be taken can be discussed and determined promptly.

Walkie-talkie sets now under test as auxiliary caboose equipment are enabling a freight-crew member on foot alongside his train to communicate with the locomotive in connection with operating difficulties or maneuvers.

In the second way, between trains and wayside base stations, the stations are located at intervals along the right-of-way varying from as short a distance as 5 miles in mountainous terrain to more than 30 miles in flat or rolling country. By means of extensive exploratory tests these stations have been established at locations where the radiated signals from any two adjacent stations overlap sufficiently to assure an adequate signal strength (of about 5 microvolts) in the receiver of a mobile station in the fringe area. The most efficient site for a base station seldom coincides with the 24-hour wayside office from which it must be controlled. Therefore, a number of the stations are remotely controlled by wire from a 24-hour office.

On each division, averaging 100 miles, a dispatcher still directs the movements of his trains by means of a special wire telephone circuit which extends over his entire territory; see Figure 9. All important locations are connected to this circuit. It is in effect a long party line over which the dispatcher can selectively call any one of these offices to give orders or to obtain information. Normally, only the receiver at each office is connected to the line, so that any one or more wayside office operators can listen in without injecting office noise. To talk to the dispatcher, the operator uses a press-to-talk switch to cut in his transmitter. These circuits in their relation to the radio base station control offices are shown in Figure 10.

While the dispatcher normally cannot communicate by radio with trains, means have been provided so that when a situation justifies he can request a base station control office to turn a switch which connects his wire telephone circuit to the radio control. Further means for remotely keying the radio transmitter enable him to communicate directly with a mobile station within range of that base station.

Without radio, it is possible for a train to be in effect "lost" in certain areas until a crew member arrives at a telephone to report location and cause of delay. With radio, since all trains and base stations operate normally on a common frequency (160.05 megacycles), the nearest base station hears all communications between trains within its range. The base station hears the report and discussion regarding a hot-box or other irregularity and can inform the dispatcher over the dispatcher's wire telephone circuit even before the train is ready to report the difficulty or unscheduled stop to the base station, enabling the dispatcher to anticipate or take protective action. Following or opposing trains within range also may hear the report and discussion of the defective train and take protective action. In any event the base station would advise trains within its range, which might be out of mobile range with the defective train. In other cases, prompt medical or other assistance has been obtained in crossing accidents and crew injuries; information regarding abnormal track conditions, flood or storm damage, and fires has made quick action possible.

The third way, between trains within range of each other, is demonstrated in a case involving safety and team work between trains, a base station, and the dispatcher. An eastbound Chicago-New York fast freight heard the conductor of another eastbound train, a few miles ahead on the same track, reporting to the base station that his 112-car train had stopped with a hot-box near a sidetrack with a capacity of only 95 cars, and that therefore he was unable to pull into the siding to clear the main track. The conductor of the fast freight advised both by radio that he had only 90 cars and that if the defective train's diesel would pull ahead to clear the switch at the west end of the siding, his train would pull into the siding, allowing the other train to back clear of the east end of the siding, and his train

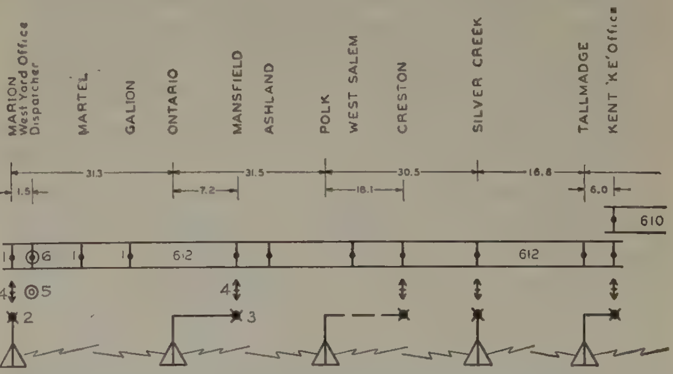


Figure 10. The circuits between the dispatcher at Marion and the radio base-station control offices are shown in this diagram. The symbols are explained in the accompanying legend

1. Office on dispatcher's telephone circuit. 2. Radio base station. 3. Radio control (remote) physical. 4. Connector unit: dispatcher's circuit to radio. 5. Dispatcher's radio control. 6. Dispatcher's office on dispatcher's telephone circuit

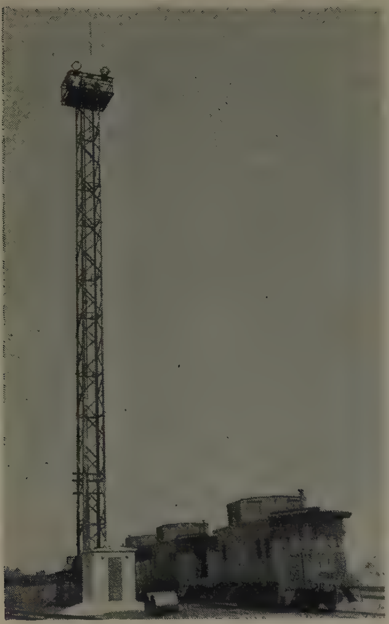


Figure 11. An antenna installation on a 120-foot floodlight tower. The rack-mounted radio units are installed in the concrete house at the bottom of the tower; this is done when the radio station equipment is remote from a control office

would continue eastward. The base station cleared the move with the dispatcher, the maneuver was co-ordinated by radio between the trains, and the fast freight proceeded eastward after a minimum of delay. The crews in both ends of each train, the base station, and the dispatcher all knew just what was occurring and an operating hazard plus a serious delay to the fast freight was avoided.

Irregularities on passing trains can be observed and reported promptly in detail to the defective train from the locomotive as well as from the caboose, particularly during inclement weather and at night when the headlight aids in such observations; for example, hot-boxes, open or swinging car doors, shifted loads, and so forth.

The fourth way is between adjacent wayside base stations. Since the base stations are located along the right-of-way so that point-to-train signal strength overlaps sufficiently to assure adequate mobile communication in the overlap area between adjacent base stations, communication between most adjacent base stations is possible due to the higher base station antennas. This permits interstation teamwork in the handling of train communication.

During serious wire line prostrations, when the dispatcher's telephone circuit and signals may be temporarily out of service, radio contact between adjacent stations and between trains has provided sufficient communication to minimize train delays greatly.

In other instances the dispatcher's remote transmitter-keying equipment and the switch connectors located at base stations to enable direct connection, when necessary, between the dispatcher (via his train dispatching telephone circuit) and trains also may permit insertion of an emergency radio link in the dispatcher's telephone circuit between two adjacent base-station control offices. Such a radio link can be used to restore temporarily the dispatcher's telephone communication in the event of a wire prostration due to a wind or ice storm, tree through the line, and so on. The link permits the dispatcher to talk to offices on his circuit beyond the break. In such cases instructions require the base station employee at the distant end of the radio link from the dispatcher to stand by to relay to the dispatcher what is said by offices at the far end of the dispatcher's circuit. This is necessary, as only the dispatcher and the two base stations involved in establishing the radio link are equipped to key the link base stations.

Where the radio station equipment is remote from a control office, the rack-mounted units are placed in a small concrete or steel house at the foot of the antenna mast. As shown in Figure 11, a convenient 120-foot floodlight tower to support the antenna is able to be utilized at times.

Because all rack-mounted units are of automatic, plug-in, unitized-construction type, all major service work on all base and mobile radio equipments west of Hornell, N. Y., is performed in a radio repair and test shop at Marion, Ohio. All such equipments east of Buffalo and Hornell to Port Jervis are similarly serviced in a shop at Hornell. See Figure 12. Each shop is in charge of an Federal Communications Commission licensed radio technician. A third shop now has been established at Jersey City to service the increased number of equipments on mobile units which do not run west as far as Hornell, also the base station equipments on the New York Division and the base and mobile equipments in the New York lighterage service. At this latter shop is a Federal Communications Commission-licensed assistant radio technician under the jurisdiction of the Hornell radio technician.

Base station units on a given division are maintained by the division telephone maintainer. When failures occur at base stations the local maintainer replaces the unit with a spare and ships the defective equipment to the appropriate radio shop for repair, where the licensed radio technician makes all transmitter adjustments.

Maintenance of the caboose axle-driven generators and converters with all mobile installations is performed by mechanical department electricians also at Marion, Hornell, and Jersey City, where opportunity is afforded to inspect regularly all radio and electric equipments. Arrangements are in effect to meet the lesser requirements at other points on the Erie.

In extending radio east of Salamanca much more difficult terrain was encountered than on the initial project be-

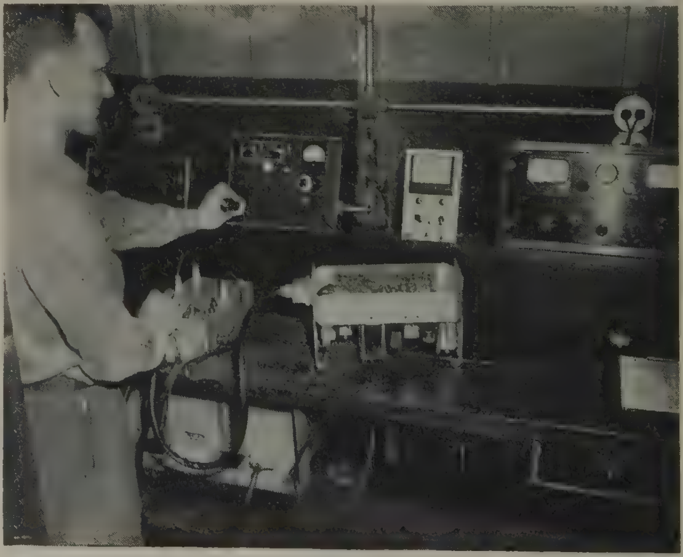


Figure 12. A licensed radio technician is in charge at each of the maintenance shops, which the Erie has to keep the radio equipment functioning

tween Marion and Salamanca. Extensive radio exploration was necessary to determine the most efficient sites for our base stations. Tentative locations were selected by an intensive study of topographic maps of the United States Geological Survey. The final sites were determined with the aid of a maintenance-type, radio-equipped exploration truck, fitted with a 40-foot aluminum extension ladder, at the upper section of which is mounted a sliding aluminum pipe with a fixed-station antenna attached to its upper end, which is shown in Figure 13.

Elevated at a tentative base station site, an antenna height of about 63 feet was obtained. As trains would come within range and radio contact was established, one of the men aboard the diesel would hold the press-to-talk button and signal strength readings would be taken from a vacuum-tube voltmeter connected to the receiver in the truck. The diesel would report as it passed each milepost, get an acknowledgment, then hold the press-to-talk button to the next milepost. This procedure would continue until the diesel was definitely out of range, as field strength sometimes increases again as a change in terrain may offer a more favorable path to the station site.

With such records of signal strength base stations were erected at locations which are effectively providing communication between train and control office through the nearest base station.

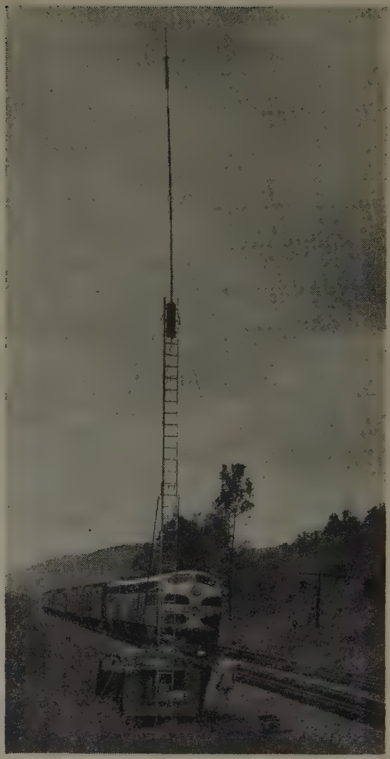
Thus, with the first complete and comprehensive main line train radio system anywhere, the Erie Railroad Company is benefiting continually in all of its advantages from New York to Chicago as well as in switching yards and terminals.

The basic radio system has been designed to operate from a 117-volt 50/60-cycle a-c power source in both the mobile- and fixed-station installations. Rotary or vibrator converters provide this power from the various d-c power sources used on the railroads. The Federal Farnsworth railroad radio system has been unitized for ease in servicing. Inexperienced personnel can change a unit easily without disconnecting wires. Unitized construction, while more costly than single packaging, better protects the user from having complete systems becoming obsolete due to changes in design and requirements of the VHF railroad radio service.

Federal Farnsworth *M304-2* a-c power unit supplies filament and plate power for the transmitter and receiver. A conventional full-wave tube rectifier, together with a choke input filter, supplies 300 volts at 375 milliamperes for the system. Two *CK 1006* gaseous rectifiers are used. Plate and filament transformers are separate and the filament transformer provides 6.6 volts at 15 amperes. The primary circuit is fused in both transformers.

The transmitter *M103* series is a crystal-controlled selectable dual-channel unit having a radio-frequency power output of 25 watts on any two frequencies spaced not more than 1.2 megacycles within the 148–174-megacycle range of the transmitter. Power output of this unit can be increased to 50 watts by the addition of a separate power supply. This unit supplies plate power to the final stage only.

Figure 13. Base-station sites are determined with a radio-equipped exploration truck fitted with a 40-foot ladder on top of which is a fixed-station antenna



In all cases in mobile installations the Federal Farnsworth employs dynamic microphones or handsets. The audio system contains necessary amplifiers and clipper circuits to limit modulation to a ±15-kc swing as required by the Federal Communications Commission. An additional amplifier can be supplied as part of the transmitter to provide an intercommunication circuit. The output of this amplifier is fed to the input of the receiver audio stages through the unit housing wiring. Intercommunication between front and rear of locomotive is then a part of the mobile system.

The *M204* series VHF receiver is a crystal-controlled selectable dual-channel unit designed for 60-kc channel separation. Maximum separation of the two frequencies is 240 kc at which point the second frequency is 6 decibels below the first frequency. The *M204* receiver is a double-conversion superheterodyne having a sensitivity of 0.75 microvolt or less for 20 decibels of quieting.

Receivers are wired for 6- or 12-volt filament operation. Plug connectors provide proper series-parallel connection of filaments depending upon the equipment rack which is used. The over-all receiver selectivity is 100 decibels down at ±32 kc and has a "nose" bandwidth of ±17 kc at less than 6 decibels down. The "nose" is essentially flat over a range of ±15 kc having peak-to-valley ratios of less than 1 decibel.

As obsolescence is a tremendous factor in radio circuits today, it has been attempted to keep this to a minimum by constructing the radio-frequency section, the second intermediate-frequency stages, and oscillator section on separate subchassis.

It will be noted that the form factor of all units is the same. This feature makes it possible to get quantity production on many of the metal parts.

The transmitter and receiver units of the Federal Farnsworth system have been redesigned twice since the original design of 1946. So far new units have been kept interchangeable with older types so that complete systems do not have to be replaced to take advantage of new designs or requirements. It is getting more difficult, however, to keep this interchangeability by the demands for narrower channel separation and other means to permit more services the use of the 148–174-megacycle band.

Sixty-Cycle and Impulse Spark-over of Large Gaps

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TESTS AT 60-cycle frequency were made by using five 350-kv testing transformers in cascade connection. The rated voltage at this connection is 1,750 kv. However, the useful test voltage was limited to 1,360 kv rms by clearances to ground of 24 feet. The 5-unit cascade is shown in Figure 1, as used for the calibration of a 200-centimeter sphere gap. The 60-cycle calibration of the sphere gap was extended to 88-centimeter spacing and checked within 2.5 per cent of the negative impulse values of this sphere gap. The output voltage of the cascade connection was measured by reading the voltmeter coil voltages of the individual units and adding them arithmetically. The output voltage of a cascade connection of five units is very sensitive to relatively slight changes in load capacitance.

Insulator strings up to 30 units and rod-gap spacings up to 260 inches were tested at 60 cycles. The rod-gap curve shows a pronounced knee at about 150-inch spacing. It appeared that the principal determining factor for this change in average spark-over gradient was the type of corona developed in the rod gap itself.

Up to 1,000 kv rms the corona on the line electrode existed as a bluish glow. Beyond that point, the glow changed into a very strong streamer discharge. The streamer advanced as much as 50 per cent into the gap without causing spark-over. The average spark-over gradient changed from 180 crest kv per foot at 10-inch spacing to 100 kv per foot at 250-inch spacing.

The impulse generator used is shown in the right background of Figure 1. It is rated 5,100-kv output. The impulse discharge circuit was arranged to give a 3x50-microsecond wave. With this circuit, crest voltages as high as 3,400 kv could be obtained. This voltage was sufficient to obtain critical spark-over of rod gaps with spacings as large as 250 inches and insulator strings containing as many as 50 units. Figure 2 shows the 60-cycle and impulse data for the rod gap. In contrast with 60-cycle voltage, the impulse spark-over voltage appears to be essentially linear with spacing. Other data indicate that this linearity continues up to spacings of 50 feet. The average impulse gradient, while decreasing from 230 kv per foot at 10-inch spacing to about 165 kv per foot at 250-inch spacing for positive polarity, appears to level out at that value. It is, however, quite possible that the impulse spark-over gradient will be reduced drastically as in the case of 60-cycle spark-over, but at spacings in excess of 50 feet.

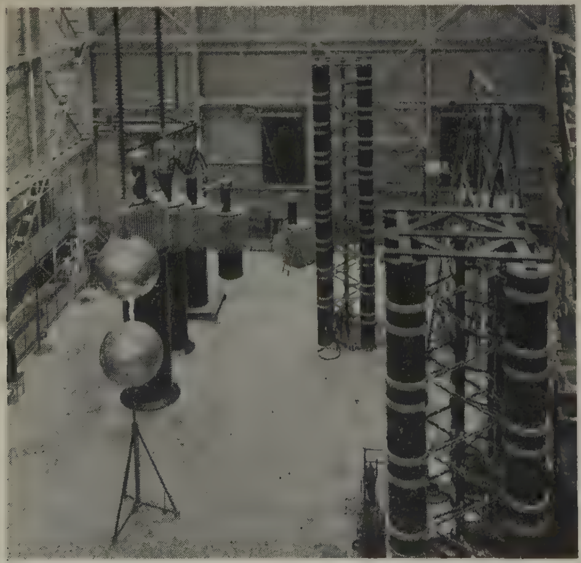

Figure 1. High-voltage test area with five 350,000-volt testing transformers connected in cascade during spark-over tests on a 200-centimeter sphere gap at 1,200,000 volts

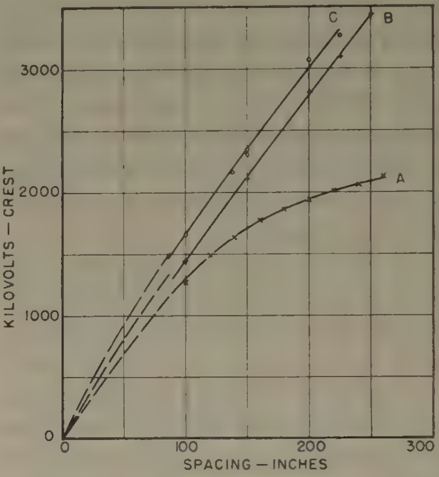

Figure 2. Critical spark-over voltages of rod gaps. (A) 60-cycle; (B) positive; (C) negative. 760 millimeters mercury, 25 degrees centigrade. Dashed lines = American Standards Association-C68 values. Solid lines = present tests

Volt-time data were obtained on the rod gap for spacings up to 150 inches and for times to spark-over as short as 2 microseconds for both polarities. During impulse tests with negative polarity at about critical spark-over voltage, a glow discharge with streamers emanated from the negative electrode together with a distinct streamer from the positive grounded electrode. This phenomenon was not observed for positive polarity spark-over. The currents involved in these impulse tests were of the order of a few amperes.

The data presented are applicable to laboratory work from the point of view of the sphere-gap calibration and should be very useful in the determination of transmission-line clearances where high lightning voltages are likely to develop.

Digest of paper **52-104,** "Sixty-Cycle and Impulse Spark-over of Large Gap Spacings," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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The Human Operator as a Link in Closed-Loop Control Systems

L. S. BEALS, JR.

Human behavior is becoming an increasingly important factor in modern engineering design. As machines become more complex, closer co-operation between bioscientist and engineer is required to achieve a fuller understanding of the human operator.

ADVANCES IN THE fields of engineering, technology, and the physical sciences have been so great in the last 10 years that biological science applied to these fields has been left far behind. Essential and crucial data relating to the human factors have become relatively inadequate to the needs of engineering designers with the inevitable result that more and more equipment is being pressed into operational service without sound scientific assurance of its human usability or habitability. This, of course, is not from the choice of either engineers or bioscientists but is the result of pressure exerted to meet urgent requirements of national defense. Since pressure of this sort seems to show little sign of abating in the near future, the disparities between what is known about man and what must be known may become even greater unless some new and effective working concept is developed.

As a result of war-born experience dealing with military equipments that violated many of the even then known principles of human use, the Special Devices Center 6 years ago established a program called Human Engineering, in which the primary goal was to apply the known principles of psychology, physiology, anthropology, and military medicine to the man-machine relationship and to equipment design, and to establish a research program for extending our knowledge in these areas.

Human Engineering, in which bioscientists work side by side with engineers in design and development, increasingly has been able to improve the effectiveness of man-machine combinations. In a paper delivered before the Special Devices Association, September 29, 1951, Dr. Detlev Bronk indicated that the joined effort of engineers and human engineers yields greater results than the sum of each working separately. There is no question but what this profitable co-operative approach must endure; the only question is how it can be modified and improved so that it makes a maximum contribution to society.

In order to recognize the relative significance of any part of the field of human engineering one must have some over-all appreciation of the total magnitude of the area. Since Human Engineering deals with the relationship between men and equipments, this can best be acquired by regarding tangibles (of a "use" rather than "esthetic" nature) and classifying them as either for human habitation, use, guidance, or control; for automatic, self-regulating functions; or for combinations thereof. In equipment of the automatic classification not requiring consideration of a human operator, the servicing and maintenance pose special human problems. It is quite evident that human factors have some significance in all equipments, and that human engineering therefore should operate to some degree in all engineering areas. Hence a problem raised for human engineering consideration will have a magnitude of importance dependent upon its relationship to the total engineering picture.

HUMAN ENGINEERING AND ENGINEERING

METHODOLOGY, OR the technique by which the capacities, limitations, and general characteristics of human beings are studied, differs from that used by the physical sciences for a number of quite obvious reasons and some not quite so obvious. First of all, each of the separate biosciences involved in human engineering for years has had its own most effective research technique, and has brought all or a part of this technique to the human engineering area. As a result there is no one single and invariable research technique in human engineering. Separate techniques contribute to a varying degree in the establishment of appropriately integrated study plans for different problems. Typically, however, in the biosciences problems are organized in terms of a single described human function, as separate from others as possible.

Furthermore, since human engineering deals with nonexpendable research material, unlike the physical sciences, tests to destruction, and so forth, cannot be undertaken. Absolute load limits on the human organism cannot be established feasibly, nor for that matter can long-run reliability studies of an engineering type be accomplished.

In addition to the differences between engineering and human engineering just described, there is one more very important and fundamental difference. Almost all of the specialized areas of human endeavor have a characteristic shorthand type of communication which is highly meaningful to specialists in the area but sounds like confusing polyglot to outsiders. Describing scientific phenomena in terms other than the special vocabulary—lay language, if you will—may result in poor description and excess verbosity. Additionally it may place the expert who has no special skill in this translation technique at

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Full text of a paper presented at the AIEE Conference on Feedback Control Systems, Atlantic City, N. J., December 6–7, 1951.

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such a poor advantage that he appears not to know his own field very well. He resents finding himself in this predicament and blames his audience for forcing him into this awkward situation. The paradox lies in the fact that his very attempts to establish better communications between himself and nonexperts actually result in rearing obstacles to good mutual understanding. Bring two such special groups together as human engineers and engineers, between whom the fullest exchange of information and viewpoint is preliminary to exerting any joint effort, and one finds the pot calling the kettle black on account of "jargonese."

Engineers are likely to dismiss much of what the biosciences group says on the grounds that the special terminology is a cloak deliberately tailored to hide a lack of precise data. On the other hand, the bioscientists confused by such words as adiabatic, stadiametric, fugoid, and Lissajous' figure find it hard to believe that engineers are not also indulging in a little too rich vocabulary.

It is assuredly the responsibility of any special group with special knowledge and skills and a desire to work with other groups to learn the best techniques for communication. Engineering and Human Engineering with a long-standing desire to work together are growing closer all the time, to the extent even that they are now borrowing vocabulary from each other.

In addition to language, vocabulary, and other communications factors there is one more item that must be fully appreciated by both the engineering group and the bioscientists in Human Engineering. It is what the engineer might regard as a liability resulting from the efforts of Human Engineering. That this is a perfectly normal and human opinion, and that it rests upon credible evidence, should be understood clearly from the following.

Before the advent of Human Engineering the responsibility for equipment design, development, production, and utilization was solely the engineer's. He has learned, however, that the fullest practical consideration of human factors in these equipment areas will assure a more effective and useful equipment. Since he is not a bioscience expert he must include one at every stage of equipment evolution, sharing with him what he considers his authority—but none of the responsibility. This sets a rather poor stage for the Human Engineer to tread but is comparatively trivial when one inspects the effect of Human Engineering on the engineer's timetable.

If Human Engineering review of an equipment design precedes actual fabrication much may have to be changed about it to conform to the human requirements. Design and redesign will take longer, obviously, than simple design, and will impose a certain awkwardness of unfamiliarity on the engineer who attempts sincerely to include good Human Engineering in his design. This is, however, the least delaying of the two methods of applying Human Engineering. The truly serious effect of Human Engineering from an engineer's point of view comes when an already existing fabricated equipment is found to violate so many important Human Engineering principles that it must be redesigned, modified, and reconstructed.

This, then, is the important thing for both the Human Engineer and the hardware engineer to realize—that Human Engineering, for the most part, will be responsible for introducing delay into the development timetable, no matter at what point it is introduced. The problem is simply to determine whether the improvements in equipment effectiveness and utility are worth more than a slightly shorter development time. This is the question to be answered in every case. If the answer is affirmative then the delays must be accepted philosophically.

The nature of the Human Engineering system of classification wherein separate functions are studied, to some extent out of context, has been referred to already. The working research principle has been that basic characteristics of certain human functions can best be studied when the variables relating to other functions were as stabilized or controlled as possible. In most biological research this is true, for the nature of variations cannot be determined when the measurements are in terms of other variables.

COMPLEXITY OF HUMAN BEHAVIOR

THE FINAL PRACTICAL objective to the study of variables is to develop enough knowledge to predict the variations, within limits, if the nature of certain factors upon which variability depends is changed. Since man is a complex of continuously dynamic dependent variables—even in his basic physiology—the problem confronting biological research is how best to classify groups of variables to the end that all but the one variable under study can be controlled within as narrow limits as possible.

Human Engineering and psychophysiology have chosen to segregate variables in man in terms of broad functions: perceiving, judging, and doing. All the sensory or perceiving functions can be considered under the category of perceptual skills (vision, audition, tactile discrimination, kinesthetics); all the "doing" functions under the category of motor skills (with or without tools and augmentation); and "judging" under diverse categories like behavior and stress responses, and fatigue.

A gross classification system of this nature serves the purpose of defining research boundaries for investigating small detailed biological characteristics but it has little functional utility in the area of applied Human Engineering. There can be no denial that Human Engineering applied to specific engineering equipment problems must consider man as much as possible as a single functioning unit and not as an accumulation of isolatable component functions, only a relative few of which are well understood.

It becomes evident that biological research data gathered under the gross functional classification system will have to be reworked or extrapolated from in order to relate the interdependent functions of a man unit. Methodologically, therefore, the problem is to resynthesize basic data and classify them if possible in terms which parallel the classification system of equipments which man will operate. This obviously will require a maximum amount of mutual understanding between bioscientists and engineers, as well as the solving of many new problems of functional covariants the nature of which Human Engineering is a long way from understanding.

Up to this point man has been considered as more or less an independent unit, and some of the more obvious complexities to be studied have been sketched. When these complexities are related to a specific task or function, like that of controlling machines, the investigator finds the complexity of the man-machine combination raised to an exponential power.

The classical example, in our experience, of the magnitude of control problems and our relatively inadequate study methodology is found in aviation. In controlling aircraft man receives certain pertinent information data from his instruments, judges, discriminates, and compares this information, and then activates certain controls which in turn change the information fed to him through the instruments. Superficially this situation, which has been called a closed-loop control circuit, appears to the engineer relatively simple. In fact, the apparent simplicity has been regarded as verified by the development of automatic pilots which can do much of this controlling. The automatic pilot containing a simple computer governing the magnitude of an error signal between program and performance undoubtedly performs one phase of aircraft control better than a human operator, but more is involved in flying, particularly military flying, than simply maintaining a steady state in three dimensions and in velocity. Control of an aircraft means over-all programing of the flight—both power-plant and airframe—maintaining a continuum of comparisons with learned standards relating to weather, fuel, terrain, engine operating limits, en-route and destination conditions, aeronautic law, communication doctrine, air traffic control, navigation, ground control approach, and perhaps a military mission.

From the Human Engineering viewpoint it can be said that only a small proportion of these factors have been studied well enough even to establish what needs to be known and then how best to provide that information to the aviator for comparison with standards he possesses. How well the aviator matches these standards throughout a flight depends upon either his ability (or skill) or the adequacy of his comparison standards, functions of his experience and training. No matter in which of the two areas he may have a weakness, the operational end-product will be measured in terms of his performance for which actually there are few good objective measuring techniques.

FEEDBACK IN THE HUMAN

An infinite number of problems relating to displays, or the information input to the pilot, obviously face the Human Engineer. However, these cannot be considered independently of the control manipulation by the aviator, which is the output function in a servo analogy.

Since the human operator serves partially as an integrator and comparator, treating inputs for value, phase, and frequency in terms of certain programed mean values as standards, it is misleading to regard this as his most important function in control and not to consider his intrinsic feedback characteristics. In this consideration this is navigating in badly charted waters from a purely biological point of view, for research has been peripheral to the central problem of how man structures his integrating comparisons.

It has been the hope in the classical study of motor skills and controls or simple synthetic man-machine feedback systems that some of the nature of how man integrates would be revealed. Theoretically it should be possible to determine the mechanical mathematics of simple closed-loop circuits if one can measure or control input and output. At the very least, the nature of how input modifications alter output value should reflect some eventually recognizable mathematical relationship which in turn could partially describe man's integrating mechanisms.

The importance of this sort of information to the practical problem of designing aircraft controls is quite obvious. Here we have a fairly simple feedback control situation. The pilot is required to change some value of X, Y, or Z co-ordinates in response to an input from his information display. To do this he displaces his stick or rudder pedals which in turn set up resisting forces imposed against the hand or foot. From these returned forces, relayed back to the point of central nervous system origin of the control movement command, information is derived by the pilot indicating how much he is controlling and whether it is over or under the desired value. Playing an important role in the generation of feedback here is the slope and description of the force versus displacement curve. Simple alteration of the variables of force and displacement will permit maximizing of control accuracy but will fail to give insight into what process of neuromuscular integration leads to low error value. Even the shape of the curve probably will not remain constant when additional variables are introduced to provide a superimposed feedback component relating to aircraft speed, or when the control function is extended in time and fatigue enters the picture.

Examination of curves for force versus displacement that have proved moderately satisfactory indicates they are biphasic sinusoids with a zero in both co-ordinates sustained within certain small limits to provide a positive null.

This is mentioned in passing because it has considerable significance for those interested in biological control elements. A choice is offered of two types of concepts for the study of biological control systems, linear and nonlinear. Convincing arguments have been heard for each but this fact should not prove any more confusing than describing a black and white dog as black with white markings or white with black markings. What occurs, as suggested by the nature of force versus displacement curves, is a combination of linear and nonlinear responses, a sufficiently frequent occurrence in physical sciences like metallurgy to be acceptable if not enjoyed. Certainly in the physiological processes all our knowledge indicates that stimulus-response patterns are never purely linear or nonlinear over their full range, but rather may be predominantly one or the other in some segment of the range.

At the risk of complicating the picture even further, however, it must be indicated that there is one very basic type of response in man which is neither of the two pure types, or a mixture, but is additional to them. The simplest biological system, the so-called "motor unit," consists of a single motor neuron, or nerve fiber, and the family of muscle fibers it innervates. It is a functional unit because it is not capable of fractional activity. This is due primarily to the kind of different response mentioned, and is described as the "all-or-none law." Under this law it is said that "a stimulus of just threshold value produces in single nerve fibers, and in individual muscle fibers excited through their nerves, a response which is maximal for the tissue under conditions prevailing at the time. Stimuli of greater than threshold value do not produce a greater response."[1]

This physiological response as a very small unit in an extremely complex biological system for motor control or for muscular activity in a man-controlled machine can be considered like a preloaded trigger mechanism. No matter how hard one pulls on the trigger only a predetermined energy release is achieved.

Many more instances could be enumerated to demonstrate the frequency and significance of atypical responses which are neither linear, nonlinear, or mixed. They have important places in the response patterns of man acting in a control capacity, but the purpose in mentioning them is only to illustrate how the concept of linearity or nonlinearity is more exclusive than inclusive.

One more example of the atypical response must be mentioned briefly, however, because it demonstrates a basic principle relating to frequency response at an elementary level. In the neuromuscular mechanism there is a frequency response unique to whatever laboratory test condition has been set up for one nerve-muscle preparation or another. Below the threshold of response appropriately timed single stimuli of subthreshold value will have an additive effect which will be of sufficient magnitude to produce motor plate discharge. Within the range of stimulus voltages above threshold, stimuli critically close together will not produce this effect because of a unique phenomenon without any good parallel in the physical sciences. This phenomenon is known as refractoriness and develops when a second stimulus is superimposed on the conducting nerve prior to full action cycling or sufficient recovery of the nerve-muscle unit. This abortive second stimulus is said to have come in the refractory phase of the cycle.

These ultrasimple biological mechanisms give evidence of different kinds of response behaviors under different relative as well as absolute conditions of quanta, frequency, and timing. While it may be statistically valid to omit two of these unknowns from the analytical process or to treat the three types of response individually, or even to assume constancy of all but the variable under study, it cannot yield very significant data for, in the neuromuscular mechanism illustrated, these are mutually dependent variables.

ANALOGIES OF MAN

Biological research aimed at ultimately knowing all there is to know of man has been progressing through an infinite number of detailed and microscopic experiments which so far have left many critical gaps in our knowledge. That some important areas of biological behavior have not been studied is not necessarily because of apathy, disinclination, or accident, but is rather because how to investigate them has not been discovered.

Approaching some of the more complex total functions man performs, often composed of hundreds of separate but interacting psychophysiological mechanisms, by the usual detailed methodology of biological research can be likened to erecting the Pyramids by putting atoms together to form molecules to form mass enough to make stones. No small wonder that the biological sciences have not enough data at hand to solve questions arising from the practical problems in the field. Continuing to prosecute only this minute sort of research will result only in greater relative inadequacies on the part of the life sciences.

Efforts to streamline biological research to match more nearly the demand for specific design criteria have produced several strictly engineering analogies, the chief objection to which is, as it is with some of the statistical procedures, that they oversimplify the biological dynamics.

The first analogy, where man is considered as a sort of ultrarefined servomechanism, fails to include some of the much more important psychological properties which often are the primary but unadmitted reason for using man in a system instead of a servo. The second popular analogy, likening man to a computer, tends to put more emphasis upon the psycho-intellectual processes of man, but is wholly unrealistic until more of the basic equations can be written.

To one versed at least in the fantastic complexities of biological measurement, and quite conversant with the gaps in our knowledge, these analogies are repugnant. This is not to say, however, that our present technique of inching forward through meticulous detail is quite satisfactory and eventually will fulfill the practical requirements for design criteria. What the biological sciences desperately need is a totally new concept and a technique wherein the valid integrated values of human behavior and performance can be selected and the detailed investigation of isolates rejected. Only through such a technique will it be possible to catch up with the functional requirements of modern engineering.

One of the most useful of the newer concepts was proposed by two Germans, Henschke and Mauch, as a result of war-enhanced aviation medicine requirements. In an unpublished paper in 1947 they approached the problem of control of machines by considering it a regulator process in which man forms a part of the regulation cycle.

In the science of regulator techniques a distinction is made between the dynamic problems and the technological. The former deal with the general regulating behaviors of a control cycle, including stability, accuracy, and speed of the regulating process, and the working principle of the regulator. The technological problems deal with the construction of the regulator.

MAN IN THE CONTROL LOOP

Applied to man the dynamic principles include formulating and describing the general behavior of man in control systems independent of the detailed specific control activity he performs. Out of this should come general principles for the best design of control systems.

A counterpart of the technological problems in man is the methods by which man checks the regulated value and how he affects it. This returns us to some of the classical separates mentioned earlier dealing with displays and controls.

In applying the principles of regulator technique to man when he is inserted as an element between other technical elements, his characteristics and responses necessarily will have to be measured in the same mathematical units as the technical elements, and his functions will have to be classified as they are.

The term "transmission system" as applied to control cycles describes a functional unit having input and output, either the sensing devices, the control element, or the regulation section, or even the whole control cycle. Within the transmission system, time, which can have a zero or near zero value only with a square-wave generator arrangement, is factored into: 1. delay time; 2. retardation time; and 3. a combination of these to make up transition time.

Obviously control cycles in which man plays a part are more or less continuous, and as such are more difficult to analyze than finite incident control cycles. It is the ultimate objective in this concept, however, to describe the output value in terms of certain time functions of the input value, as Henschke says, "the steady-state transmission ratio" or frequency response. This relationship should provide a clearer picture of the dynamic behavior of man in the system. The needle in our mathematical and technical haystack is the description of the transition function of our human element.

Since man cannot be stabilized to the degree that technical elements can, variables introduced into a complicated system provide output changes the real significance of which cannot be determined. Henschke suggests that man can be induced, however, to act within definite limits by inserting him in a control system in which the only unknown is man's transition function. Measurement, if not detailed understanding, of the transition function then can be accomplished with some assurance.

Other techniques exist, of course, for studying man in control cycles, and one in which some moderate skill has been acquired is that employed in the Special Devices Center projects on systems analysis. Here the approach is to study man in the actual control situation using simulator equipments the constants and variables of which are well known, and which can be given any selected value.

The technique is not unlike that of putting an unknown technical control element into an electronic computer which has been instructed on all the other elements in precise mathematical form. Running a problem through such a system will provide input to the unknown element. There the inputs are converted into control outputs, the operational significance of which can be weighed at the end of the computer system, as though one actually had accomplished an operational mission.

After having actually measured numbers of biological elements in the complete control cycle under study there is perhaps one more analysis technique to which these measurements could be submitted. Several high-frequency digital computers with great memory capacity have been developed for logistic and sociological study. Such computers, having the special facility of dealing with coded entries, should make it possible to duplicate the behavior of complex man-machine control systems without having to duplicate any part of the studied equipment. Over-all performance of a system, the effect of biological elements upon it, and, hence, some understanding of the natures of biological elements should be practical of attainment through this kind of research.

No matter what special control functions are assigned to man in a control system it is certain that unlike technical elements or automatic controls, a human controller will introduce many undesirable response features. One of the more obvious of these is response delay, or transition time, made up of perceptual time, discrimination time, and reaction time. Mechanical elements need not be so affected by time delays. Equally as apparent is the unpredictability of motivation, fatigue, and intellectual distractions unique in the human element and requiring no consideration in automatic systems.

Special advantages of biological elements, however, leading to their choice over automatic systems are versatility, trainability, modifiability in the midst of a control operation, and rather marked overload capacity, for short time periods, at least.

Of these advantages versatility is perhaps the most outstanding, but in reality it also is the one single characteristic that produces most of the complexity in studying human control characteristics. It imparts a certain quicksilver nature to the problem so that an apparent solution merely fractures the original problem into several new fragmentary problems. Sometimes it initiates such a series of nonterminal fragmentations that the original control problem becomes lost in a jumble of complicated dead-end problems the solutions to which seem less and less likely to be attained. The phenomenon can be understood more easily if it is borne in mind continuously that "versatility" simply means that the human organism in most cases has multiple mechanisms and systems for solving any particular problem, including that of control. If one mechanism of the controlling organism is occupied with another task, any one of several others may be chosen for the newest problem. Furthermore, while habit and training may tend to make one or two mechanisms statistically more probable in any given control situation the effects of emotion, fatigue, or operational emergencies may reduce this probability to zero.

In the study of man as a special element in a control system, therefore, the task is not alone to determine his transmission function but also to determine it for the most probable of the several mechanisms that could be selected by the controller. The best environment for this sort of study is obviously the actual control situation, or a simulation of it, as suggested earlier.

When it comes to designing an actual control system and the choice must be made of either an automatic or a biological type, or a mixed type, the engineer must weigh some of the probable advantages against predicted limitations, many of which have been identified.

Within the concept of regulator technology man is not suited for regulations of high quality unless it is more important to exploit those assets mentioned. What distinguishes man from an automatic transmission system in a regulation process is a vital central nervous system with sensory inputs. If this is essential to regulation then man is the directed choice for a control mechanism.

CONCLUSIONS

It has been pointed out that engineering now is making greater demands on the biosciences for human design criteria, particularly in control systems, than can possibly be met as long as research clings to a molecular methodology. To determine how man structures his discriminations, and what his response capacities and limitations are, a molar approach such as has been proposed must be adopted generally in the study of biological control elements. At the present time the choice of man as a control for complex functons must rest more on hope and optimism than on fact and knowledge.

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Co-ordinated Transportation for Metropolitan Communities

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Traffic congestion in large centers of population exacts a staggering toll in inconvenience and financial loss annually. Alleviation of this condition has taken the direction of expediting vehicular movement, but the fundamental problem is moving people. Co-ordinated transportation systems offer attractive possibilities.

If ANYONE were to select groups of men who have done most to improve our American way of life over the past 30 years, engineers would certainly be nominated for a top place on the list. Menial tasks in home, field, and factory have been lightened tremendously and the time they consume greatly reduced. Radio, television, and other modern means of communication have greatly increased the volume and speed of transmission of messages, music, and entertainment. Transportation of people and goods has made great strides in all forms: automotive, aviation, and rail.

Probably the greatest exception to this wonderful progress is found in the retrogression in speed and convenience of movement in our cities. Many billions of dollars have been spent for wider streets and for limited access highways; for elaborate bridges, tunnels, overpasses, and underpasses; for traffic controls and signs, and for facilities to park vehicles off the streets. In spite of these Herculean attempts to permit transportation in the private automobile, traffic congestion in our cities grows steadily more acute.

A recent issue of the *Reader's Digest*, under the title "Ah, Prophecy," quoted the following from the 1899 *Scientific American:* "The improvement in city conditions by the general adoption of the motor car can hardly be overestimated—streets clean, dustless, and odorless—with light rubber-tired vehicles moving swiftly and noiselessly over their smooth expanse would eliminate a greater part of the nervousness, distraction, and strain of modern metropolitan life."

On the other hand, a recent issue of *Roads* said that "Horse-drawn carriages used to travel an average of 11.5 miles per hour in New York midtown traffic. Today the average speed of the automobile being used on the same streets is 6 miles an hour." A friend of mine recently asked, "Shall we walk or have we got time to take a taxi?"

SPACE LIMITATIONS

The real essence of the problem is that we do not have—and never can have—enough streets, freeways, tunnels, bridges, and parking space to permit the movement of all people and goods over paved streets and highways. Consider New York, for example. It would require 12 to 15 6-lane grade-separated parkways to provide the same passenger-carrying capacity as a 4-track subway; see Figure 1. Not only this, but where would you park the cars delivered by such wide expansions of multiple freeways?

Recently we were shown a brand new building on the Miracle Mile of Wilshire Boulevard in Los Angeles, Calif. The far-seeing planners had heeded the admonition that

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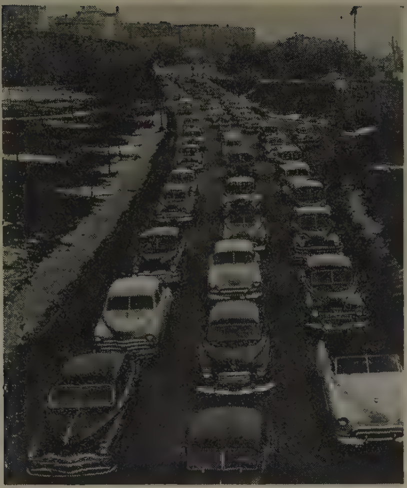

Figure 1. Rush hours on a "high-speed" (?) freeway. One track devoted to rapid transit is the equivalent of 8 to 12 such freeways

it would take the floor area of another building of equal size to park only the cars of the workers in the building, if they all came in private autos. Of course, over and above those working in the building there are customers and clients who wish to come there too. Automobile parking space exceeding the total floor area of the building was provided beside and behind the building. The manager of the enterprise took us to the roof to see the result. The parking area was full and cars were cruising about the lanes to find parking space. His comment was, "We'd fill twice that parking area if we had it!"

Similar experiences are reported from all over the country. The larger the city the more acute the problem. In Detroit, Mich., the great Hudson Department Store finally found it necessary to set up branches on the periphery of the city. In their own words, "We had to concede the fight to the high and mighty automobile—after all, Detroit spawned the millions of automobiles which have created the traffic congestion and parking problems plaguing all urban centers."

One very large corporation recently decided to move its office building out of downtown New York City, far out into the suburbs. In developing the project, parking space, just double the area of the building, is being provided on the assumption that all their people will drive to the building. These folks have become realistic about the amount of parking area needed. Try to visualize what would happen if all New York shops and offices decided to follow this course. That sounds preposterous; but there is no mistaking the fact that this trend is very active at present. Primarily it results from our lack of a solution of the problem of speeding up the movement of people and goods in large urban areas.

TRANSPORTATION COSTS

Viewed from the standpoint of the individual, the whole problem is one of time, convenience, and cost for all his travels to and from work, recreation, school, and church. Few people stop to think of the cost of traffic congestion in terms of the great delays in the movement of goods. All this lost time and wear and tear on trucks and delivery cars must be paid for by the consumer. Traffic congestion today is costing our country billions of dollars annually. It is estimated that street congestion in New York robs the merchants of over $1,000,000 a day. Boston, Mass., estimates the cost of trucking delays at over $40,000,000 annually. One authority states that downtown Detroit real estate values have dropped a billion dollars in 15 years, primarily because of the delays and inconvenience of moving in and out of the city.

MOVING PEOPLE

A few relationships in the moving of people will exemplify the problem. One lane on a city street, with cross traffic, can move a maximum of about 1,500 passengers per hour in automobiles. On grade-separated freeways the figure is about 2,500 passengers per hour. In comparison, a public-transit lane on a city street with busses, trolley coaches, and streetcars can move 9,000 to 13,000 passengers an hour. A single track of express rapid transit can move as high as 60,000 passengers per hour.

Here is still another way of viewing the problem. Passenger car registrations have increased more than 60 per cent compared to the period just prior to World War II. About half of the automobiles, approximately 20,000,000, are urbanly owned or operated on city streets. There they travel some 100 billion vehicle-miles annually. This

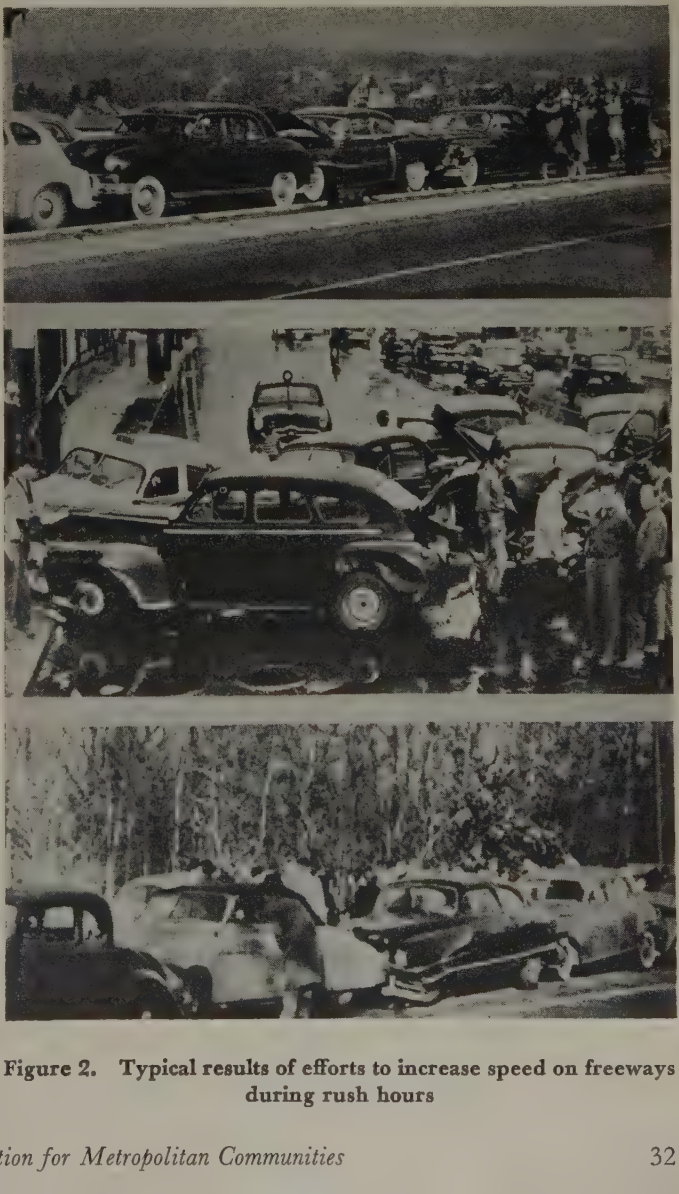

Figure 2. Typical results of efforts to increase speed on freeways during rush hours

Figure 3. Traffic congestion in our cities is reducing automobile speeds to less than a walk

horde of vehicles produces about twice as many passenger rides as do the public-transit vehicles. These number some 87,000 or about 1/2 per cent of the number of private autos. They travel about 3 billion miles or roughly 3 per cent of the mileage traveled by the autos. Based on comparable carrying capacity, the vehicle ratio is about 115 to 1 and the mileage ratio about 16 to 1 in favor of public transit. Of equal importance is the fact that public-transit vehicles require relatively little parking space because, outside of stopping to load and unload passengers, they keep moving continually and when not in use they are stored off the street.

HOW THE PROBLEM MAY BE SOLVED

These comparisons obviously lead to the conclusion that a major step in the solution of the traffic-congestion problem is to promote greater use of public transit. This is a simple observation to make, but much careful planning and hard work will be necessary to bring it about. The healthy way to accomplish this objective is to build up public-transit systems in our metropolitan areas to a point where they will attract a substantially greater number of riders. In the larger population areas this involves not only public transit but also railroad commuter services operating over a radius of 25 and even 50 miles from the city centers. These services must be modern, clean, attractive, and speedy as judged by today's standards.

It is important that the trunk lines for long-distance commuting be as free as possible from cross-traffic interference and also from the congestion of vehicle concentration experienced on our most modern freeways and parkways. In large metropolitan areas, this can be best accomplished through the use of high-speed rail services completely separated from automotive traffic of all kinds. This network of high-speed trunk lines should be supplemented by a short travel-distribution system employing both the private automobile and the modern public-transit vehicle: busses, trolley coaches, and streetcars.

Examples of Large Cities. It is most interesting to note that these conclusions are being reached in one large community after another. In July 1951, the New York Regional Plan Association made public its interesting and thorough studies of the New York commuter problem. The conclusion reached was that development of rail transportation facilities had lagged far behind that for automotive vehicles. Recommendations were made that ways be found to bring the high-speed, rapid-transit, and commuter developments abreast of those already made for handling rubber-tired vehicles. Further it was recommended that the problem be considered as area-wide and that there be an adequate co-operative effort between the various states, public-transit systems, and railroads to bring this greatly needed development into being. Some excellent considerations and suggestions were voiced in William Reid's address at the Sixth Regional Plan Conference in New York City on October 9, 1951.

Other cities have developed, or are considering, plans for the installation and major expansion of high-speed rail rapid transit. The Boston metropolitan area, through its Metropolitan Transit Authority, has outlined a substantial increase in rapid-transit services. It is working toward this end as circumstances and financing permit. Primarily the plan involves using branch line railroad rights of way for its extensions, and envisions financing backed up by general lien credit. Chicago is expanding its rapid-transit system and is endeavoring to demonstrate that this can be accomplished through revenue bond financing. Cleveland is starting its rapid transit, utilizing right of way established for that purpose when the Union Terminal project was developed years ago. Financing in this case is also on a revenue bond basis. Toronto, Canada, is well along with its first rapid-transit route: North-South Yonge Street project. The financing is on a revenue basis but the system, in the final analysis, does have the backing of Toronto general lien security. Active studies of rapid transit are under way at Los Angeles, San Francisco, St. Louis, Detroit, and other large metropolitan areas.

Financing. It is becoming evident that most serious consideration will have to be given to future methods of financing which will have to be employed to raise the large amounts of capital necessary to accomplish the results desired. A considerable amount of people hold the well-justified opinion that these projects, particularly the rights of way, will have to be financed through general lien

Figure 4. Transportation by private automobile requires parking areas double the floor area of the building served

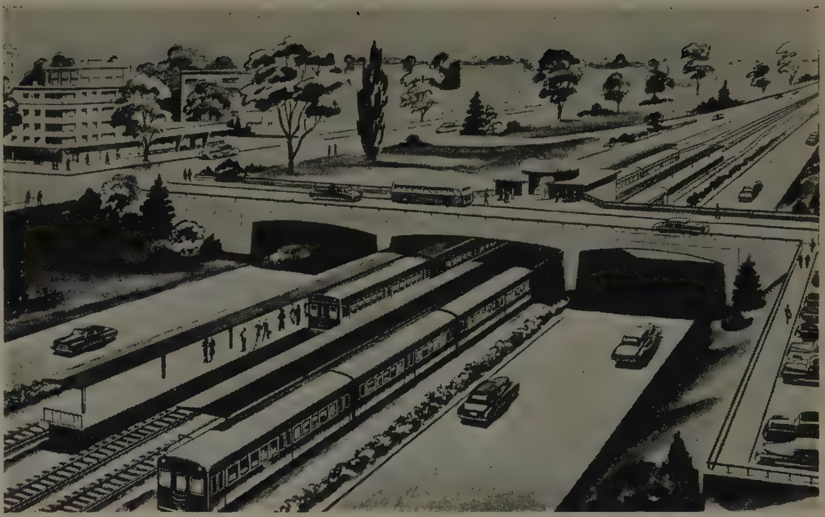

Figure 5. These four lanes of rapid transit are equivalent to 12 to 15 6-lane freeways and patrons require no parking areas

credit. This thinking is on the theory that these rights of way cannot be fully supported out of passenger revenue and that they should not be fully supported out of such revenues because all people in a large metropolitan area benefit by a modern rapid-transit system, whether they use the services or not. It makes the movement of people to all points of the area faster and more convenient. It also contributes in major fashion to traffic congestion relief with consequent reduction in expenses resulting from less traffic delays. In other words, rights of way for rapid transit should be considered in the same class as other community services, and should be the responsibility of the community at large.

Since communities now provide a very considerable share of the streets, parkways, bridges, tunnels and so forth built to handle automotive traffic, it seems logical that under the same considerations of responsibility they should provide the rights of way for high-speed rail rapid transit. They contend that the taxpayer's investment per peak passenger handled for the long-trip rider is tremendously less for high-speed rail facilities than for paved freeway lanes, however important both may be. This appears to be well founded when one considers their relative capacity; for instance, a double-track subway line is equivalent to some 12 to 15 6-lane grade-separated highways. Moreover, public-transit riders do not require major parking areas for their automobiles.

Rapid-Transit Rights of Way. There are numerous means of providing rights of way for high-speed rail rapid transit. No doubt all systems in our large communities will come to use some or all of these. Probably the most expensive is the subway with excavations made specifically for rapid transit. This construction will be required in downtown areas, particularly where no other possible right of way exists. In certain locations the elevated structure will still be desirable; however, the consensus of opinion is that this structure reduces the value of business streets. In general, it will be eliminated gradually to improve streets by the reduction of noise and the increase of light and fresh air. One of the less expensive methods of obtaining rights of way is to make full use of already existing railroad tracks. This applies to both those now devoted to commuter services and to branch lines which do not now handle capacity traffic. In some instances there are railroad rights of way available which at present are used very little or not at all.

Another inexpensive source of right of way for rail rapid transit is the center mall of a freeway, included in the original design. It is estimated that high-speed rail rapid transit rights of way so provided can be obtained at a cost on the order of one-tenth the cost of subway construction. It is tremendously important that any freeway being installed in our large metropolitan areas be thoroughly studied from the viewpoint of future need of rail rapid transit, and provisions made for it if the studies so indicate. The common experience is that freeways built are never wide enough; so if the center mall lanes are not devoted to rail rapid transit, they can be devoted to automotive use and their capacities will never be wasted.

A very practical problem is immediately posed: how to provide the financing for the two or four center mall lanes desired for rapid transit. This must be solved separately from the financing of the automotive freeways which, in most instances, involves not only local but also State and Federal highway funds. Whatever method is used, the financing should be set up to embrace the complete metropolitan area including the commuters' suburban home communities, even though these arrangements may involve several states. The Authority type of organization seems best suited for such a large and diverse undertaking.

Operation. The operation of such lines can be undertaken either by the Authority, or by a private enterprise under contract. The city of Philadelphia has an arrangement whereby it provides a certain portion of the rapid-transit financing and contracts with the Philadelphia Transportation Company for operation. It has been suggested that private-enterprise contracts could carry major incentive provisions to enhance both maximum patronage and greatest efficiency of operation. For example, a certain amount per passenger handled could be given to the private carrier contractor. This would result in the contractor doing all within his power to increase the number of patrons. Further, an additional amount could be given based on the percentage of fixed charges earned out of fares over and above operating costs with specified standards of operation and maintenance, and agreed rates of interest and depreciation.

Excellent studies have been made blocking out desirable rapid-transit systems for many of our large communities. These fine engineering recommendations have withered on the vine after their completion, largely because their importance was not thoroughly heralded to the general public and because the task of forming the necessary organization to design and finance the project looked much too tremendous for anyone to undertake.

Electronic Regulation of Metallic Rectifiers

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LARGE INSTALLATIONS OF communications equipment, industrial control devices, and computing instruments have given rise to a demand for d-c power supplies having the property of maintaining a constant load voltage. The concentration of such loads in 10-kw units makes it economical to devote development time and first-cost expense to the rectifier installation; and this new dimension in economics has induced considerable development engineering effort in the direction of higher efficiency and more accurate voltage regulation in these power supplies.

In this type of regulation the quantity to be adjusted is measured continuously and automatically, and the output of the measuring device is used as a means of providing the desired adjustment. This is the familiar closed-loop technique in system design.

Metallic rectifiers in themselves do not offer any means for controlling or regulating d-c output; and where they are employed in regulated rectifiers other circuit elements for separate means for adjusting the output must be provided. One common and successful method of adjustment is to change the a-c input to the rectifier bridge.

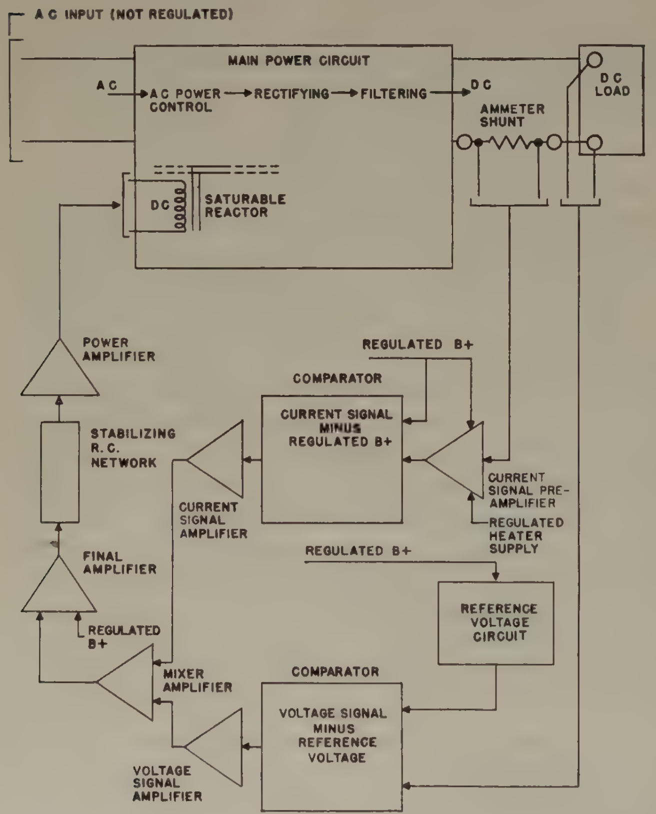

Figure 1. Functional schematic electronic regulating circuit applied to regulated rectifier

A conventional design for the main power circuit is taken as a starting point—that is, the whole of the regulated metallic rectifier exclusive of the electronic regulator part of the loop—and technical details only of the automatic control of the saturating direct current in the saturable reactor are given.

The electronic device must have an output rating ranging from 50 to 100 watts, depending upon the size and design of the main power circuit employed. The circuit illustrations are limited to one electronic system design as shown in Figure 1.

Starting at the d-c load terminals, the regulating signal can be traced through the feedback regulating loop. The signal first is passed into the comparator; and thence through the voltage signal amplifier, the mixer amplifier, the final amplifier, the stabilizing resistance-capacitance network, the power amplifier, and into the d-c winding of the saturable reactor. The automatic adjustment of inductance in series with the a-c input power effects a constant load voltage. However, there is a second signal input to the feedback loop, originating at the ammeter shunt. This second signal is proportional to the load current, and finds its way into the saturating winding by way of the current signal preamplifier, a comparator, a current signal amplifier, the mixer amplifier, the stabilizing resistance-capacitance network, and the power amplifier. This current-sensitive regulating path is designed to perform the function of limiting output current to a safe magnitude as a feature overriding the demands of the voltage signal which calls for constant output voltage.

It is customary in systems having a storage battery in the load circuit to provide part of the peak load by allowing the battery to discharge, and to recharge the battery during off-peak periods when the load is less than rectifier capacity. In systems like that described here the voltage-regulating feature holds the load (and battery) voltage constant for all fractional loads. The load voltage-current characteristic is horizontal to full load, and vertical beyond full load, with a rounded knee connecting the two portions of the curve. The rounded knee is caused by the transition between voltage regulation and current regulation.

This drooping load regulation characteristic is reversible; and is stable as regards current and voltage adjustments, after initial operation has removed drift effects due to the aging-in of the current preamplifier triode. The performance is ideal for loads including a storage battery in that the charge is restored automatically to a partially or fully discharged battery as rapidly as is consistent with the continuous current rating of the rectifier.

Digest of paper 52-100, "Automatic Regulation of Metallic Rectifiers by Electronic Control," recommended by the AIEE Committee on Metallic Rectifiers and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Not scheduled for publication in AIEE *Transactions*.

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Electrostatic Neutralizer Discharge and Safety Characteristics

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Static electricity in industry is a menacing problem to production and personnel. Presented here is an evaluation of various types of static neutralizers with test data showing their comparative effectiveness to assist engineers in selecting suitable antistatic equipment.

THE RAVAGES OF static electricity occur quite generally throughout the gamut of industrial processes wherever the stock or products manufactured and used possess insulating properties. In a few typical operations among the textile, paper, rubber, and plastics industries, conventional means of controlling static electricity are applicable by the use of so-called static neutralizers. To the author's knowledge no technical information is available showing test performance of static neutralizers which enables one to select antistatic equipment with a predetermined degree of assurance or satisfaction.

In many hazardous industrial operations, on the other hand, no simple and ready-made antistatic expedients are available. The host of specialized problems here can be resolved only by applying tailor-made prescriptions for the control of the static electricity causing potential fire and explosion hazards.

To assist safety engineers and plant personnel in a more discriminating choice of suitable antistatic equipment, the AIEE General Industry Applications Committee requested the author to prepare a compehensive article classifying the various types of static neutralizers, explaining their relative advantages and limitations, appraising their degrees of safety, and presenting test data to show the comparative effectiveness of static neutralizers within each classification.

All industrial static neutralizers utilize the principle of ionizing the air at locations where the offending electrification on the processed stock exists, whereby vast numbers of negative and positive charges are created in the intervening space between the units and the stock. The electric charges thus formed in the air which possess opposite polarity to those generated and accumulated on the stock are attracted to, and thus neutralize the charges on, the electrified stock. If a sufficient number of charges in the ambient ionized air are available to neutralize all of the charges of opposite polarity, complete discharge occurs.

When a voltage capable of creating ionization is impressed across a gap, the resulting process of creating negative and positive ions from high-velocity free electrons is referred to as "ionization by collision," the collisions being between the high-energy electrons and neutral atoms. This characteristic growth of electron population as ionizing electrons rapidly advance toward the positive plate in vastly increasing numbers is known as an "electron avalanche."

The alignment of negatively electrified metallic points with a nearby ground rod greatly affects the electric field distribution in the gap, creating a field pattern of high distortion, especially near the points. The concentration of electric field at a needle point when it is negatively electrified immeasurably increases the potential gradient there for a given applied voltage, a condition which multiplies the ionization activity at the negative point and thus accounts for the much lower spark-over voltages for needle-point gaps.

If a discharge point to a nearby ground rod is electrified to positive polarity, the formation of negative and positive ions in the gap is decreased markedly in comparison to that for a negative point. Of course, the geometry of both electrodes plays an important part in the process and magnitude of ionization by collision. When a point to a nearby ground rod is energized with alternating potential, copious ionization occurs for a part of the half-cycle when the point is highly electrified to negative polarity. The ionization, on the other hand, is relatively small for the succeeding half-cycle when the point is electrified to positive polarity.

HIGH-VOLTAGE PREIONIZING NEUTRALIZERS

ONE METHOD of causing ionization, referred to as "preionization," employs high-voltage stressing of the air between electrified point electrodes and nearby grounded members, the latter for most effective ionization constituting a built-in part of the neutralizer unit and being herein called a "proximity ground." The high potential impressed on the ionizing points is provided from one terminal of the high-voltage coil of a transformer while the other terminal of the coil is connected to the ground rod, as illustrated in Figure 1*A*. When the electric stress at the points attains the breakdown value for air at a potential gradient in the order of 31 kv per centimeter, under standard atmospheric conditions, ionized air pervades the intervening electrified space between the points and the grounded member.

Obviously, ionizing points connected conductively to

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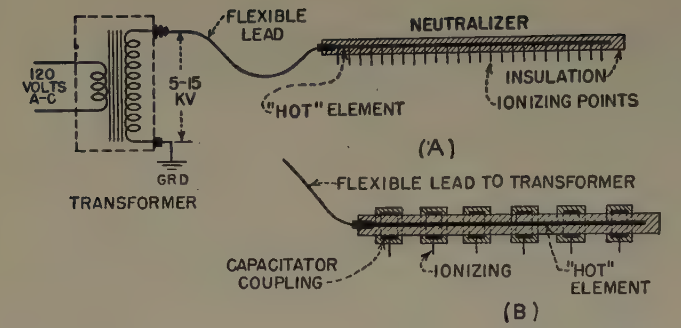

Figure 1. (A) Hot electrode of an a-c neutralizer connected conductively to ionizing points. (B) Capacitor coupling to the ionizing points for increased safety

the "hot" element of the neutralizer and energized directly from a high-voltage transformer, as shown in Figure 1*A*, introduce hazards of fatal shock to an individual who touches or receives sparks from the electrified points. One means for reducing this potential hazard which is incorporated in all high-voltage neutralizers comprises the use of capacitive coupling of the ionizing points to the "hot" element of the neutralizer bar, as shown in Figure 1*B*. A neutralizer employing this principle is classified as a high-voltage preionizing unit with proximity ground. Several of the high-voltage neutralizers which utilize proximity grounds embody the ground feature in the form of an outer metal encasement rather than a ground rod. The ionizing points in some of these are the ends of flexible fine wire bristles insulated from the grounded encasement by vulcanite or ceramic centering elements.

Neutralizer bars which do not employ proximity grounds also cause ionization of the ambient air, when energized, although much less copiously. A few static neutralizers are constructed to operate in this manner. To increase the relatively low ionization at the points, transformer voltages in the order of 12 to 15 kv are utilized in these neutralizers whereas, in neutralizers employing built-in proximity grounds, transformer voltages in the order of 5 kv are employed more commonly.

PREIONIZATION BY RADIOACTIVITY

ANOTHER MEANS FOR ionizing air utilizes the emission of alpha particles from the spontaneously disintegrating nuclei of radium, polonium, or other radioactive isotopes of the heavy metal elements. The ionizing range of alpha emission in air is limited to an effective distance of about 3 inches. Neutralizers which utilize alpha emission from radioactive isotopes to ionize air also are classed as preionizers.

The radium activator in a radioactive neutralizer possesses a theoretical half-life period of 1,690 years. In practice, however, the effective life of a radium neutralizer, aside from its mechanical durability, is determined by the length of time the exposed side of the thin gold and nickel envelope containing the activator can be cleaned of alpha-absorbing deposits without inflicting permanent injury to the fragile metallic membranes.

A disadvantage of the radium neutralizer, aside from its eventual loss of effectiveness by absorption of alpha radiation, lies in its additional emission of beta and gamma rays. The former possess distinctive erythemal properties which in prolonged exposure injure skin tissue, while the latter, like hard X rays, penetrate deeply into body tissue and cause harmful secondary emission.

Polonium, unlike radium, possesses the very short half-life period of 144 days, although neutralizers using polonium as an activator are claimed to have an effective life of over a year. An advantage possessed by polonium neutralizers results from the emission of alpha particles without appreciable amounts of the detrimental beta or gamma radiation.

IONIZATION BY ELECTROSTATIC INDUCTION

THE SECOND GENERAL classification of neutralizers is one which employs the principle of ionization which is dependent on electrostatic induction rather than preionization. Neutralizers of this class comprise a miscellany of bars wrapped loosely with grounded tinsel, grounded jewelers' wire, and many configurations of grounded metallic bristles and arrays of sharp points which are variously disposed along metallic or wooden supporting bars. These neutralizers derive their ionizing facility by electrostatic induction from the electric field of the electrified stock. One such induction neutralizer is illustrated with relation to the stock it is discharging in Figure 2.

The voltage between the electrified stock and the tips of the grounded metallic bristles electrically stresses the intervening air. As the potential gradient at the tips of the grounded bristles attains the threshold value for ionization, discharging action by the liberated electrons and positive ions is initiated at the surface of the electrified stock. When the potential gradient at the tips of the bristles exceeds the threshold of ionization, the discharging facility of the induction neutralizer greatly increases because the ionization is an exponential function of the increased induction voltage.

The disadvantage of induction neutralizers lies in their inability to start discharging electrified stock until the potential gradient at the tips of the grounded bristles attains the threshold value for ionization. Where stock is highly electrified, induction neutralizers when properly constructed possess definite physical and economic advantages.

TESTING THE DISCHARGE PERFORMANCE

TO SIMULATE BY laboratory tests the industrial conditions under which static neutralizers perform their service, a careful analysis of all the variable parameters

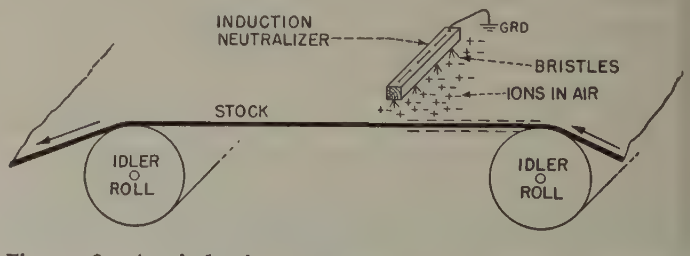

Figure 2. An induction neutralizer with grounded metallic bristles

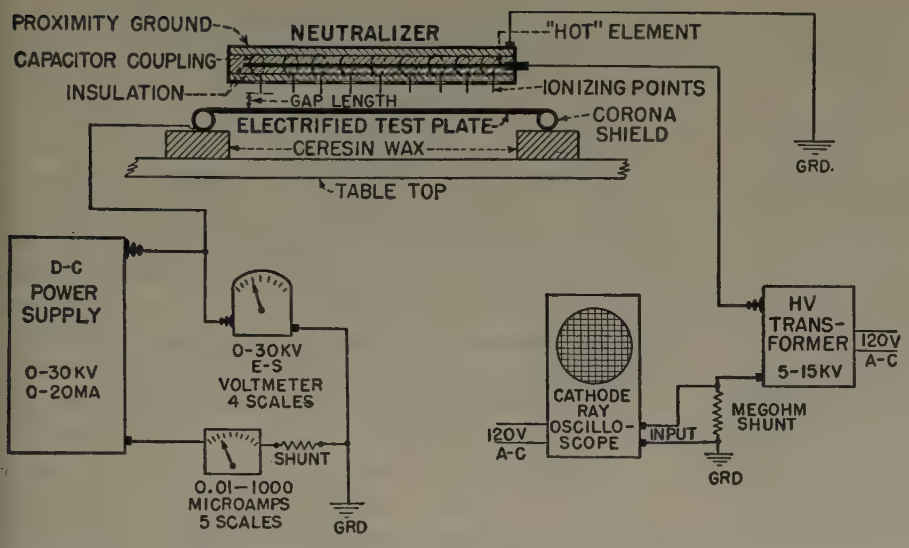

Figure 3. Circuit used for testing static neutralizers

affecting the operation of these devices becomes paramount.

An anticorona polished metallic plate was employed to represent the electrified stock. This plate was electrified from an appropriate d-c power supply with controls to apply any desired voltage up to 15 kv. The practical elimination of leakage current from the test circuit was achieved by insulating the test plate and other high-voltage parts from the work bench by blocks of ceresin wax.

The static neutralizer under test then was suspended across the test plate and equipped with its supplementary facilities. These consist of energizing the static bar with its rated transformer voltage in preionizer units, of grounding the proximity ground, if such is used, or of grounding the housing of radioactive neutralizers or the metallic bristles of induction neutralizers. The gap spacings between the neutralizer bar and the test plate employed in the tests were 0.75, 1.00, 1.25, 1.50, and 2.00 inches. The neutralizer effectiveness in discharging the test plate was measured by the value of direct current supplied to the test plate from the d-c power supply. The test circuit is shown schematically in Figure 3.

In practice, the discharge of highly electrified stock composed of fibrous materials, such as textiles and paper, is augmented by the fibers attracted from the surface into the gap not only by virtue of the ionizing properties of the fine semiconductive fibers but also by the reduction they cause in the effective length of the gap. In plastic and rubber stock, the smooth surfaces of these materials largely remove these variable ionizing factors except for slight effects from roughened edges. The anticorona polished test plate was designed intentionally to eliminate from the tests these variable factors.

Also, the varying direct voltage, existing between the electrified stock and ground, which the neutralizers are expected to reduce or eliminate, introduces into industrial applications another variable factor. In the discharge tests, this uncertainty was precluded by maintaining constant voltage at the electrified test plate. Hence, the discharge facility of each neutralizer during test was accurately presented by the direct current through the microammeter from the d-c power supply to the test plate.

Since the processing of many stocks over steel rolls commonly electrifies them with negative polarity, the test plate was electrified to negative potential, although at least one set of data for each neutralizer was taken for comparative purposes with plate positive.

THE DISCHARGE FACILITY OF NEUTRALIZERS

THE NEUTRALIZER UNITS supplied by the manufacturers were all prepared to a common 12-inch effective length. The units which were tested are displayed and classified for reference in Figure 4. The individual neutralizers are labelled with code letters for reference to the performance curves.

The test results portraying the characteristic discharge facilities of the neutralizing units at the indicated gap lengths are displayed in Figures 5, 6, 7, and 8. The discharge characteristics of the high-voltage preionizing neutralizers with proximity grounds, units A, B, C, D,

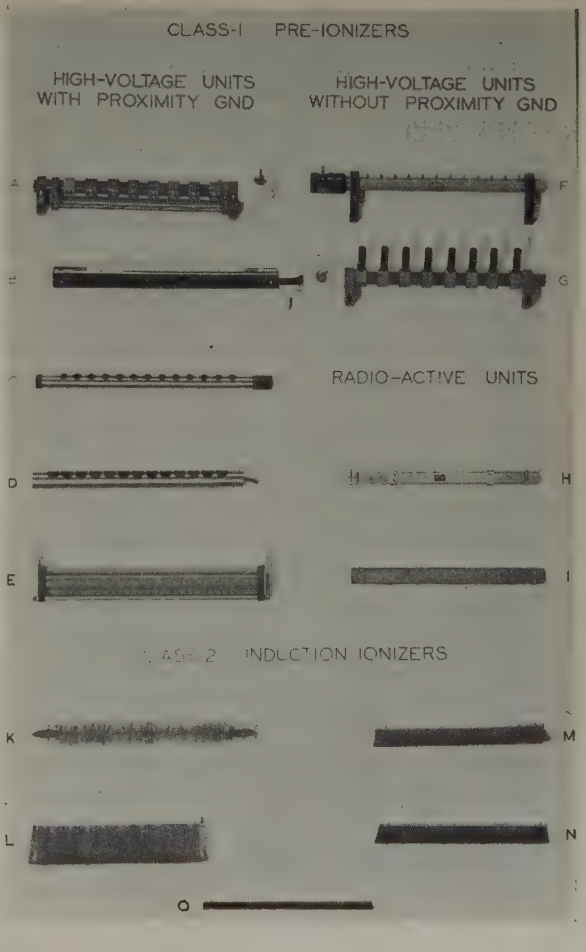
CLASS-1 PRE-IONIZERS
HIGH-VOLTAGE UNITS WITH PROXIMITY GND
HIGH-VOLTAGE UNITS WITHOUT PROXIMITY GND
A
F
B
G
C
RADIO-ACTIVE UNITS
D
H
E
I
CLASS 2 INDUCTION IONIZERS
K
M
L
N
O

Figure 4. The neutralizers which were tested. Code letters refer to performance curves in Figures 5, 6, 7, and 8

and E, shown in Figure 5 for a 1.00-inch gap, appear to possess close linear response to the varied d-c electrification of the test plate.

Actually, if the electrification of the test plate could be increased indefinitely without spark-over to the a-c neutralizers, all of the ions in the ambient air would be appropriated for discharge purposes as rapidly as they are formed, and, for this reason, the rate of discharge would decrease. Hence, the curves of discharge current, as a function of the d-c electrification of the test plate, gradually would approach the horizontal as occurs for any saturation curves. This typical saturation for a-c neutralizers is shown by all of the discharge curves in Figure 6 for the 1.50-inch gap except for unit D and this, too, would saturate at higher electrification.

In Figures 7 and 8, the discharge current for the radioactive neutralizers, units H and I, is substantially independent not only of the range of d-c electrification employed in the tests but also of the lengths of air gaps utilized. The ions of the ionized air within the gap space resulting from the alpha bombardment are wholly appropriated for neutralizing the impressed charges on the test plate by attraction resulting from d-c electrification as low even as 5 kv. Hence, the higher voltages of the d-c electrification can attract to the test plate no more ions than those produced by this constant rate of ion production, thus providing the flat discharge characteristic shown by the solid lines.

In the alpha emitter the discharge current decreases when the test plate is electrified to positive polarity. The electric field from the plate, in opposing the movement of the positively charged alpha particles, slows their speed and thus decreases their ionizing properties. For the radium neutralizer, the discharge currents for both the 0.75- and 1.00-inch gaps are gradually reduced from 0.25 microampere, in each instance, at 5-kv plate voltage to zero at 15 kv. The polonium neutralizer similarly shows evidence of this submission effect on the speed of the alpha particles by the positive field influence. These unique discharge characteristics are indicated by the curves with the dashed lines in Figure 7.

Also in Figures 7 and 8, the high-voltage a-c neutralizers without proximity grounds, units F and G, are seen to yield strikingly low discharge currents in comparison with the discharge currents in Figures 5 and 6 for the high-voltage a-c neutralizers with proximity grounds.

Special tests demonstrated that grounded machine members on the opposite side of electrified stock from a neutralizer without proximity ground, contrary to general belief, provided substantially no increased effectiveness in the ionization of the neutralizer. On the other hand, if grounded members were located on the same side of the electrified stock as the neutralizer and within an inch or so of the ionizing points, the ionization and the discharge current caused by the neutralizer as a result of these artificial proximity grounds increased severalfold.

The discharge curves in Figures 5 and 6 show that induction neutralizers, units K, L, M, N, and O, do not start ionizing until the threshold potential gradient of ionization is attained at voltages ranging from the order of 7 to 13 kv, depending on the gap length. However, when ionization once starts, the discharge current increases rapidly as an exponential function of the direct voltage existing between the test plate and the grounded bristles of the neutralizer.

Grounded members near the bristles of induction neutralizers divert the electrostatic field of the electrified stock from the bristles, thus reducing the potential gradients at the tips of the bristles, and, hence, decreasing the discharge current. Or, if the grounded machine members are located close to and on the reverse side of the electrified stock from the neutralizer, the increased localized capacitance between the electrified stock and ground decreases the potential of the stock and, therefore, reduces the induction and the discharge facilities of the bristles.

PROXIMITY EFFECTS OF IONIZING POINTS

THE SPACING DISTANCE between ionizing points along a neutralizer bar is a critical element of design which influences to a marked extent the degree of ionization under established conditions, and hence affects the magni-

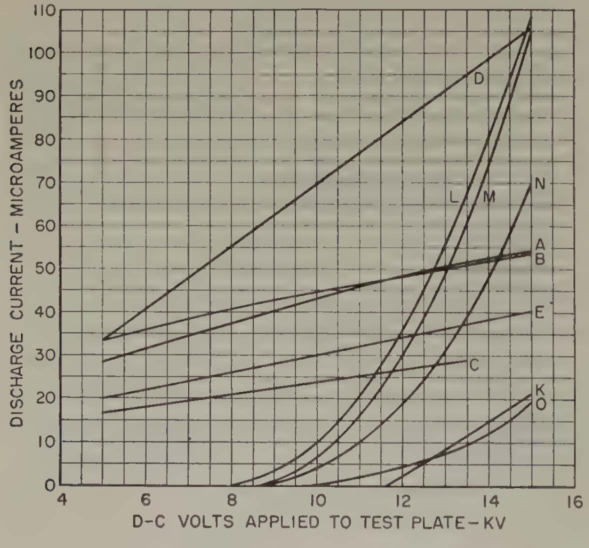

Figure 5. Neutralizer discharge characteristics with 1.00-inch gap length

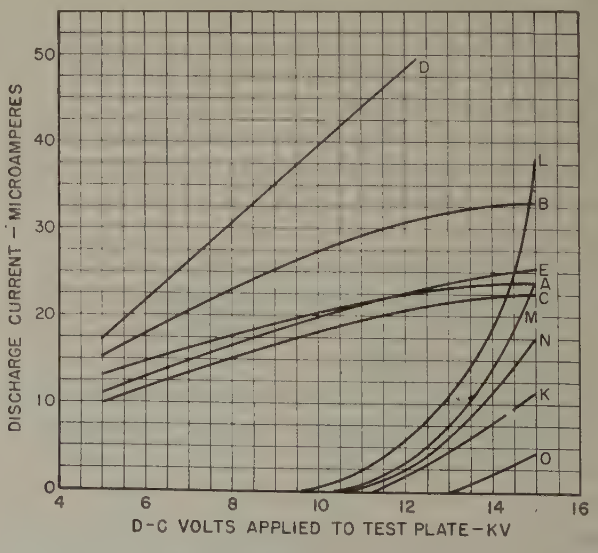

Figure 6. Neutralizer discharge characteristics with 1.50-inch gap length

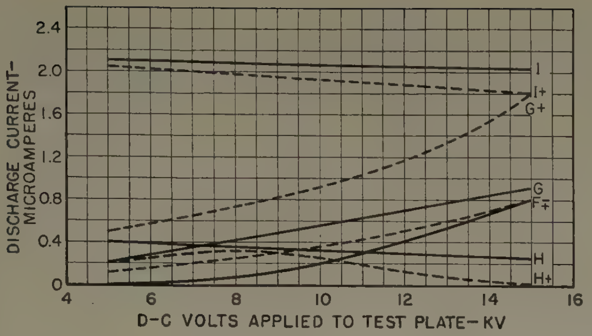

Figure 7. Characteristics of radioactive neutralizers (H, I) and high-voltage preionizers without proximity ground (F, G). Dashed lines are for positive test plate. Gap length, 1.00 inch

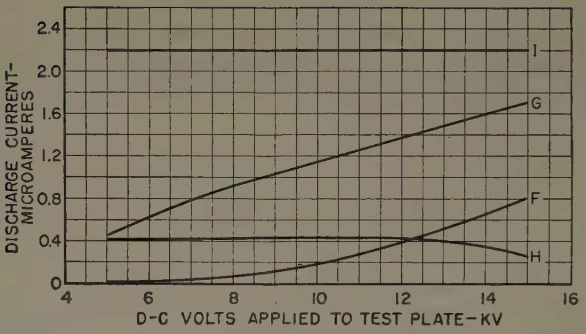

Figure 8. Same test as Figure 7 with 1.50-inch gap length

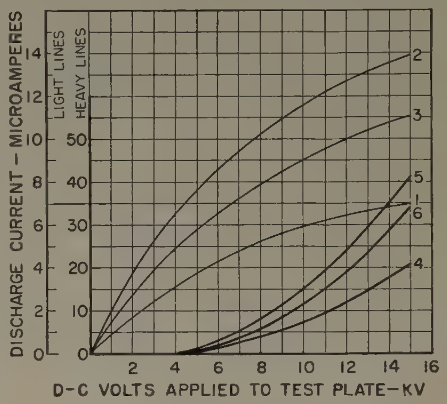

Figure 9. Discharge characteristics. 1. Single a-c ionizing point with proximity ground. 2. Two such ionizers $8^{13}/_{16}$ inches apart. 3. The two ionizers 13/16 inch apart. 4. Single needle induction ionizer. 5. Two such needles $8^{13}/_{16}$ inches apart. 6. The two needles 13/16 inch apart

tude of the discharge current both for high-voltage preionizing units and for induction units. If two ionizing points on a high-voltage preionizing neutralizer with proximity ground are separated by several inches, then for a constant a-c excitation of the points, constant d-c electrification of the test plate, and constant gap length, the discharge current is nearly double that for a single point. If, however, the two ionizing points are moved nearer and nearer together, the discharge current no longer remains double that caused by a single point but appreciably diminishes in value. This proximity effect for two such preionizing points may be observed by reference to the light-line curves in Figure 9.

In testing the proximity effect of grounded needle ionizers subjected to electrostatic induction, first a single needle was located over the test plate with the same gap length as for the ionizing points of the high-voltage preionizing unit. Then two needles were used and separated by the same distances employed in the previous tests of the preionizing points. Curves showing the discharge current with respect to the electrification of the test plate for the ionization by induction of the single needle and the two needles with spacings of $8^{13}/_{16}$ inches and 13/16 inch also are included in Figure 9 for comparison, as shown by the heavy lines.

Obviously the proximity effect is particularly high in any brush-type neutralizer in which the wire or other bristles are literally packed solid, such as in units L, M, N, and O; and, under this condition, in addition to passing a relatively low discharge current, the threshold voltage of ionization becomes maximum.

DEGREE OF DISCHARGE CURRENT REQUIRED

In the calendering of ply-stock for rubber tires, in the coating of textiles with rubber or plastic compositions, and in various other processing operations at low speed in which the voltage to ground of the electrified stock ranges in the order of 25 to 50 kv, the electron density on the stock lies in the general order of 100 billion electrons per square inch of surface. The low speed at which the stock is processed in these operations ranges for the most part between 10 to 50 yards per minute. Under these conditions with stock moving at, say, 20 yards per minute, the rate of movement of electrons in a foot width of the electrified stock lies in the order of 10 trillion (10^{13}) electrons per second which, for complete neutralization, corresponds to a discharge current in the order of 1 microampere.

This figure of discharge current per foot of stock width indicates that the radioactive neutralizers and the high-voltage preionizing units without proximity grounds, the performance data for which are shown by the curves of Figures 7 and 8, appear to meet more or less satisfactorily the requirements imposed on them by these industrial processes. In other kinds of processing where voltages are encountered in the order of 100 kv or more and especially where the speed of the stock is several times higher than 50 yards per minute, such as in rewinding operations of nylon and of other highly insulating stock and in newspaper printing, neutralizers of these types could not be expected to yield complete neutralization of the electrified stock.

On the other hand, the copious a-c ionization and the high discharge currents disclosed by the data in Figures 5 and 6 indicate that the high-voltage preionizing neutralizers with proximity grounds provide ionizing facilities capable of completely neutralizing stock under even the highest industrial electrification, such as in newsprinting, the manufacture of plastic films, and the embossing of wallpaper. Where such high-voltage electrification occurs, induction neutralizers of the metallic-brush type, when properly designed and constructed, also perform well.

The high-voltage preionizing neutralizers with proximity grounds appear from the test data to provide ionization and discharge currents far in excess of the requirements for many industrial processes. While a vast excess of ions in the ambient space around the stock after its neutralization causes no ill effects, neither does it possess any virtue. Manufacturers of the electrostatic equipment could best improve safety by using lower voltage equipment, thus avoiding potential shock hazards from vicious high-voltage sparks, and providing maximum safety from ignition of flammable fuel-air mixtures.

ELECTRIFYING AND DISCHARGING STOCK

In nonconductors, practically no free electrons exist, although electrons can be liberated from surface atoms by the influence of powerful extraneous electric fields, ultraviolet radiation, or X rays. Of more importance in static electrification is the liberation of electrons from surface atoms by virtue of the electrical unbalance of intra-atomic forces at the interfacial boundaries between contacting areas of different kinds of substances.

When contact occurs, electrons migrate from the substance of higher dielectric constant to the substance of lower dielectric constant through the many points of surface contact. The electron migration continues until equilibrium of the superimposed system of electric forces at the interfacial boundaries is established. The phenomenon is correctly known as contact electrification, although frequently it is erroneously referred to as "frictional" electricity. Actually friction plays no part in electrification other than to present more points of contact between contacting substances.

If one of the two contacting substances is a poor conductor, the electrons are impounded at the local areas on the one substance to which they migrated and, when separation of the two substances takes place, especially if it occurs rapidly, they remain impounded where they migrated. If separation occurs slowly, a large proportion of the electrons may wiggle back to the other substance from whence they came before final separation occurs and relatively low electrification results. Thus high-speed processing may give rise to higher electrification than low speeds on substances which are not excellent dielectrics and the common run of stock processed in industry is not highly dielectric.

Since the acquired electrons or the residual positive ions in either instance reside at the surface of the stock, electrification is a surface phenomenon. Processed stock commonly is electrified to negative polarity, hence the stock is provided with vast numbers of excess electrons more or less uniformly distributed over the surfaces.

While the contact electrification of the two sides of the stock is generally of the same polarity when the stock passes between identical steel rolls, it may differ considerably in amount on the two sides. Localized surface contaminations or variations in homogeneity of the stock on one side with respect to the other account for these differences in degree of electrification.

As a limiting case, consider stock passing over an idler roll. The stock is obviously electrified by contact on one side only; but, as tests have repeatedly demonstrated, the other side also normally becomes charged to the same polarity and intensity. That this situation occurs gives unmistakable evidence of the inherent powerful electric forces which are at work within the electrified substances to cause equalization of charge.

In certain instances, such as in the printing industry, where stock in rotogravure presses passes between a rubber roll and a copper printing cylinder, the stock may be electrified by contact with opposite polarities on the two sides. Ordinarily, recombination and readjustment of the charges of opposite polarities occur through the paper, leaving both sides of about equal and like polarity.

By the same token, a static neutralizer of appropriate type, when located on either side of the stock, discharges it regardless of whether the stock is electrified to positive or negative polarity or whether areas of opposite polarity exist on any one side.

SAFETY FEATURES OF NEUTRALIZERS

The use of capacitive coupling between the "hot" central conductor of a neutralizer bar on high-voltage preionizing units and the ionizing points has already been mentioned and illustrated in Figure 1*B*. This safety provision is important as a means of reducing potential fatality by touching or receiving sparks from the ionizing points. Maximum safety is attained by providing each point individually with capacitive coupling. One such neutralizer, in addition to the capacitive coupling, utilizes high resistance in series with each ionizing element to control even further the inherent safety of the unit against electric shock.

Another important safety provision is the incorporation of high leakage reactance in transformers which energize the neutralizers. By so doing, the short-circuit current and the sparking current directly from the transformer is maintained well below potential electrocution values, the threshold alternating current for which lies in the general order of 100 milliamperes.

As a significant test of the sparking intensity for each neutralizer, the tip of the little finger of one hand was brought within sparking range of the ionizing points. In some instances, intense involuntary muscular response occurred. If attendants were thus shocked by sparks while working on operating machinery, they could receive serious consequential injuries by being caught in gearing, rotating or reciprocating parts, and travelling belts or stock. In other instances, no noticeable muscular reaction occurred from feeble spark discharges and, for two neutralizers, the only noticeable perception of ionization was a characteristic sensation of electric breeze near the points rather than actual sparks.

SUGGESTION FOR IMPROVING NEUTRALIZERS

The manufacture of static neutralizers and the supplemental equipment has not been influenced by integrating forces directed toward co-operative improvements of these products. The unique character of the equipment has attested to the ingenuity of the manufacturers. Much of the equipment has been well constructed, utilizes excellent engineering design, and provides satisfactory operation. On the other hand, some of the equipment is improperly designed, possesses inherently the very fire and explosion hazards which it is provided to control, and is unsafe with regard to electric shock and potentially dangerous sparks which may cause operators to receive consequential injuries from machines to which it is applied.

Objectives of Engineering Education

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FELLOW AIEE

THE YEAR OF 1952 marks the hundredth anniversary of the establishment of the American Society of Civil Engineers, which was the first engineering association in the United States. The middle of the last century was a turning point in man's way of life from a social system in which survival was attained through great physical effort to one in which natural resources are utilized to relieve the burdens of mankind. It was a turning point from a low standard of living to one of high standard. It was the start of a century of progress.

The middle of the last century also marks a new era in American education. Critical appraisals of the traditional educational pursuits prevalent 100 years ago revealed that their real value to humanity depended on their applications. To assure the ultimate usefulness of academic knowledge, American universities established new educational programs to provide training in the applications of the arts and sciences—thus starting what is now called engineering education.

Engineering is responsible for the social and economic progress that exists in this country today, but the fundamental aims of the engineering school—to develop men with mental integrity able to deal with new problems and new situations—have not changed much in the last century.

ORIGINS OF ENGINEERING EDUCATION

IT WOULD BE difficult to establish the exact origin of engineering education. Long before the establishment of the first engineering schools much of the university activity centered around college courses which were in many respects engineering in nature. They were frequently classified as philosophy. On January 9, 1808, Samuel F. B. Morse, an undergraduate, wrote to his parents: "I shall be employed . . . during the vacation in the Philosophical Chamber . . . to perform a number of experiments in electricity." In another letter he tells how the instructor had his class hold hands while he administered a shock to this human series circuit. The instructor who demonstrated these early experiments was trained in theology and he was nicknamed the Pope of New England. He taught such courses as composition, dialing, disputing, and electricity. He did not teach disputing just to enable his students to win arguments. His real objective was to train students to think clearly, to draw accurate conclusions, and to express them convincingly. His objective was not to develop subject matter but to develop men. He sought to develop men with ability to deal with new problems and new situations—men with mental integrity—men who are undistorted by their own personal feelings and prejudices.

The aims of a true education have not changed since the early days of Samuel F. B. Morse and the objectives of our engineering school are not unlike those prevalent when our engineering schools were first established. We still teach electricity. We teach mechanics. We experiment in many types of philosophical chambers commonly called laboratories, but the subject matter is only the vehicle by which the student develops mental disciplines. A course in engineering provides many special disciplines that are not found in other academic courses. Since engineering is an exact science, it provides the student with an excellent means of checking the accuracies of his reasoning. Through engineering deductions or through experimentation the engineer can always determine whether he is right or wrong. Generalities and intuition are not accepted by the engineer; to him they are only substitutes for the basic thinking and for the exactitudes that characterize the engineering profession.

THE RESULTS OF ENGINEERING

MUCH PROGRESS has taken place in the United States since the time of Samuel F. B. Morse. The installation of 40,000,000 telephones is overshadowed by the number of radios, which in turn are yielding to television. The Bell Telephone System alone employs approximately a half million people. The development of this system is the work of the engineer.

Today 87,000,000 kilowatts of electric power are installed in the power plants of this country to ease the burdens of mankind. This available power is equivalent to 0.8 horsepower for every man, woman, and child through the 24 hours of the day—that is engineering. The transportation facilities provided by rail and by auto surpass those of any country on the globe—this is the result of engineering. The airways of this nation now covers 78,000 miles—this is a product of engineering. In 1900, the horsepower per worker installed in our factories was 2.5; in 1950 it was 7.5. Evaluating a horsepower as equivalent to 10 times the power of a man, the average factory worker is therefore supported by the equivalent of 75 slaves—this is progress through engineering. During the past 100 years man has increased the available power to the individual by a ratio of 100. He has increased the speed of communication by a ratio of 30,000,000. He can send a message around the world seven times in a second. Unfortunately it sometimes requires years to get this same

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Revised text of an address to the freshman class at Yale University, New Haven, Conn., October 9, 1951.

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information from the outside to the inside of a human skull. During the last 100 years man has increased the speed of transportation fiftyfold. The use of power in the world today is no longer secondary to food and shelter. Without power the food and shelter could not be provided.

Why are we so fortunate in being able to enjoy this phenomenal standard of living? Since the time of Christ there have been in this world approximately 30 billion people. Less than 3 per cent of these individuals have ever enjoyed freedom as we know it and more than 40 per cent have suffered from malnutrition. Man alone cannot supply his own physical needs. A human being is very frail. Even a competent athlete working at his full capacity over a period of a day can do about the same amount of work as a 1/10-horsepower motor operating during the same interval. Such a motor is little larger than the human fist. The energy required to operate such a motor throughout a day is worth approximately 4 cents. A human being consumes approximately $2.00 worth of food per day but in return his useful mechanical output is worth only 4 cents. How can civilization exist when the output of the individual is so much lower than his required input? The answer is simple. The difference between his needs and what he is able to produce is supplied from natural sources. The utilization and control of natural resources for the benefit of mankind is the work of the engineer.

Engineering is responsible for the social and economic progress that exists in this country today. One hundred and fifty years ago the black deposits in the earth known today as coal were worthless. Through science and engineering coal has found vast utilization. If all the coal in the United States were converted to electric energy and sold at the average rate of 4 cents per kilowatt-hour, it would provide a return of $300,000,000,000,000. This is approximately 1,000 times the annual income of this country. The value of anything depends on the use to which it can be put to supplying man's needs. The development of the use of coal has created national wealth—this is engineering. The engineer creates wealth. The economist attempts to control its distribution, but he does not create it.

Progress is not made by laws and regulations. The purpose of law is to guide. A standard of living is raised only through invention, research, development, and production. Kettering's invention of the electric starter placed a tremendous amount of electric equipment under the hoods of American automobiles. The amount of horsepower installed every 10 years in these cars in the form of starting motors is more than that present in all the powerhouses of the country. This one invention has prevented the breakage of 60,000 human arms annually—this is engineering. But Kettering did not invent the starter because of any law or regulation. No law or economic control could have ended peasantry on the farms without the reaper, the tractor, and the insecticides that are the result of engineering. No law could have ended the slavery of women without the carpet sweeper, the washing machine, the automatic laundries, packaged foods, and woven fabrics. They have lengthened the span of life. They have provided freedom and social progress.

THE NEED FOR TRAINED PERSONNEL

OUR STANDARD OF living in this country is not something that came about haphazardly. The United States has only 6 per cent of the world's population and only 5 per cent of its area, yet it accounts for approximately half of the world's production of useful goods. The strength of a nation is not determined by its conquests. It is determined only by its effectiveness in the use of its physical and mental resources. Up to the present this country has shown considerable intelligence in utilizing such resources. However, today we are faced with some dangerous statistics. Our social system is in great need of men trained in the art of maintaining and advancing this system. At present we are threatened with a great shortage of such personnel who have had engineering training.

It is estimated that we are in immediate need of 60,000 engineers. Industry also needs 30,000 engineering graduates annually for normal replacement and growth. College enrollments show that the production of engineering graduates has tapered off from 25,000 in 1952 to 12,000 in 1954. If present draft policies continue only 6,000 engineering graduates will be available in 1954. Industrial and government research has increased 500 per cent in the last 10 years and the numbers of engineers has hardly doubled.

The situation is still more alarming when we see Russia training 30,000 engineers per year and 100,000 scientists and technicians. This shortage of engineers has resulted in high salaries for the engineering graduates. It would be unfortunate if these possibilities of employment and high salaries were to attract students to engineering who are unqualified for an engineering profession. These rates of pay, resulting from the law of supply and demand, indicate the value of an engineer to society. They indicate that the qualified engineering graduates will have abundant opportunity to apply their engineering training and to earn respectable remuneration for their services. They indicate an increasing demand for engineering graduates.

LACK OF PUBLIC UNDERSTANDING

MUCH CONSIDERATION has been given to the causes of this reduced enrollment in our engineering schools. Conditions that have brought about the present dilemma can be attributed largely to a lack of understanding on the part of the American public as to the importance of engineering. The products of engineering are used and appreciated without any general appreciation of the efforts of the engineers that have made these products possible.

The average American gets great pleasure in his new automobile. He knows the location of the starting button but he knows nothing about the starter. He knows how to manipulate the gas accelerator but he knows nothing about the efforts of the engineer in making the fuel. Oil for the crankcase can be purchased at a filling station, but why worry about the processes at the refinery. If the automobile is too slow for a particular trip modern man takes to the air. He appreciates the airplane as a means of high-speed travel, but he seldom considers the enormous effort that has gone into the research, design, development, and construction of this device by the mechanical, electrical, chemical, metallurgical, and industrial engineers that have made the whole device possible. He sees the graceful body and wings of the ship but he never stops to realize that in this 4-engine transport there is installed more than 19 miles of wire. Man has enjoyed the use of his radio, but he does not stop to realize that more constructive ideas and intelligence have gone into the design of the microphone than have passed through it in its normal use.

He may know that the cost of penicillin has dropped 96 per cent during the past 10 years, but he does not stop to realize that this reduction has resulted from engineering processes that did not exist prior to the start of World War II. He reads reports of guided missiles traveling through space at a rate of 3,000 miles per hour, but he does not realize that this performance has been made possible only through engineering techniques which were unknown 8 years ago. He is well aware that we were victorious in World War II, but he does not realize that this war could not have been won without the radar, the proximity fuse, and the atomic bomb. He has a great respect for the atomic bomb, but he does not realize that this device was made in a plant which had installed in it more than 19 miles of electric switchboards. The public is very much aware of the products of engineering—it is unaware of the engineering.

Another factor contributing to the shortage of engineering registrants has been our educational system. How many students in American high schools and preparatory schools have ever encountered an instructor who is a graduate from an engineering curriculum? The absence of such personnel in our secondary schools has resulted in a lopsided preparation of the college entrant. Furthermore, during the freshman year of college, students are advised to schedule the liberal subjects and are warned about the great danger of early specialization. Such advice has done great damage in our educational system. While a few immature students should be discouraged in making a choice of their profession in their early college years it is also true that most college freshmen today are competent to make such decisions and that they should be encouraged to do so. Part of the purpose of a college education is to train the student to plan a future, to make definite decisions, and to follow them to their ultimate completion. Delay in making decisions on the part of the student can result, in many cases, in habits of complacency and inactivity that prevail after graduation, much to the detriment of the individual. Diligence should be encouraged and practiced at all times. Freshmen should not delay in making definite decisions in planning their careers. These plans should then be pursued consistently.

OPPORTUNITIES FOR STUDENTS

FRESHMEN ARE always afforded many opportunities. They have the opportunity to develop into perfect failures and also the opportunities of great success. Failures are in store for the complacent and success for those who have a purpose in life. Four years of attendance at a university does not assure a student of an education. Selection by the student of courses that he likes or those which give him the least discomfort may provide a comfortable 4 years' existence, but it cannot develop a scholar. Reading the books of the moldy past may contribute greatly to drawing room conversation, and it may lead to a display of pseudo-brilliance, but it does not guarantee that the graduate has anything to offer to his fellow men. There is a vast difference between an education and a massage.

Engineering by nature is an exact science. Naturally, engineering courses require accuracy and rigid mental disciplines. Opinions are not trusted in the engineering profession, they must be proved. In an engineering office controversies always yield to logic. Acceptance of logic requires the highest personal integrity and honesty. The qualifications of an engineer reach far beyond his technical competence. He must be able to use his training to direct materials, money, and men to a useful end. A mere appreciation of his skill is not enough. He must be able to put it to good use for the benefit of mankind.

The purpose of a university is education, and therefore the purpose of an engineering school is to provide an education. The faculties of our engineering schools have set up definite programs whereby this purpose can be fulfilled. These faculties are cognizant of the relative importance of various university courses, and they have designed the engineering curricula with due regard to relative merits of these courses. They are also aware of their responsibilities to the students. The engineering professor is not so much concerned about academic freedom as he is about academic responsibility—the responsibility to provide a valid education.

ECPD Young Engineer Training Program

An organized program to aid young engineers in the first five years of professional development through the medium of a network of local committees made up of professional practising engineers is being sponsored by the Training Committee of Engineers' Council for Professional Development (ECPD). The committee has drawn up a 6-point program to aid the young engineer in the right type of training, indoctrination, and self-analysis. The program presented examples of orientation and in-service training, continued college education, introduction to community service, indoctrination in characteristics, responsibilities, and ethics of the profession leading to recognition through registration, self-appraisal for the purpose of orientating personal plans, and of selected reading for professional and personal growth. The committee proposed that an extension director be employed to organize the resources and agencies which might help in establishing programs in communities.

The Bevatron Power Plant

J. V. KRESSER
MEMBER AIEE

The physicists' attempts to achieve increasingly higher particle acceleration require power equipment comparable to that used in a steel mill. The bevatron power plant design is based on such factors as high peak power, low input swings, and exact pulse timing.

THE UNIVERSITY OF California Radiation Laboratory is constructing a high-energy particle accelerator called the bevatron. Initial operation will be at a level of about 1.5 billion electron volts; later the energy level will reach some 6.5 billion electron volts when accelerating protons. The bevatron is a type of proton-synchrotron, although it also can be used to accelerate deuterons and alpha particles. These accelerators differ from familiar cyclotrons in that the orbit of the particle is constant rather than a spiral. Thus, the field strength of the magnet must be increased as the particle accelerates to keep it in an orbit of constant radius. Theoretically the vacuum chamber in which the particles are accelerated could be in the form of a torus with a proper magnet to provide a field perpendicular to the plan of the torus. Actually, as shown in Figure 1, the vacuum chamber will consist of four curved portions of rectangular cross section and with a radius of curvature of 50 feet, connected by four straight sections, giving a total orbit length of nearly 400 feet. The pole pieces will project into this vacuum chamber and the magnet yoke will surround it completely. The field coils are wound separately for each quadrant (the space between the sides of the vacuum chamber and the inner surface of the magnet yoke), the turns being parallel to the orbit and in two sections, upper and lower. The straight portions of the chamber will contain the accelerating electrodes, the vacuum pumps, and the injector.

Particle acceleration is obtained during a flux pulse such as is shown in Figure 2. The magnetic field is built up to a maximum of 16,000 gausses by increasing the current through the coils. Particles are injected at a rather low field value with an energy of 10^7 electron volts about 30 milliseconds after the start of the field build-up. At that time the accelerating voltage has a frequency of about 0.36 megacycle. As the particles accelerate, the frequency of the accelerating voltage must be increased so that maximum voltage of the proper phase will appear across the accelerating electrodes the instant the particles reach them. As the field builds up the frequency is raised to a maximum of about 2.5 megacycles, the build-up requiring about 1.75 seconds. During this time the particles make about 4,000,000 revolutions, travelling more than 300,000 miles. After reaching its maximum value the field must decrease to zero and a new pulse must start after a short off period. The peak power at maximum field is 100,000 kw and at that time the stored magnetic energy is about 82,500 kilowatt-seconds. This stored energy must be removed from the magnet before the next pulse can be started, and therefore it is returned to the supply system so that the only energy consumed is that due to losses.

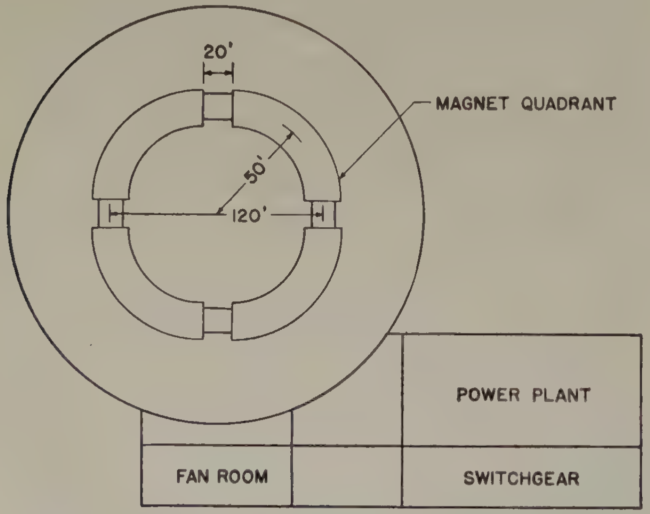

Figure 1. Schematic plan of the bevatron building

The magnet power supply requirements were given extensive study and many different combinations were analyzed. The system finally chosen is shown schematically in Figure 3. It consists of two flywheel motor-generator sets that supply energy to the magnet through ignitron power converters. During the build-up part of the pulse the converters act as rectifiers and supply direct current to the magnet windings. As the current in the magnet winding increases, the motor-generator sets slow down, with the flywheel furnishing most of the energy required. When the peak of the pulse is reached the converters operate as inverters and the stored energy of the magnet is returned to the system by accelerating the motor-generator sets. The motors supply only the losses of the system. Each motor-generator set consists of a 3,600-horsepower 8-pole wound-rotor motor, a 67-ton solid plate flywheel, and a quadruple 3-phase 8-pole synchronous generator. The generator is rated 46,000 kva, 3,200 volts line-to-neutral, 12-phase, 55.8 cycles. The rms current for each phase of the quadruple Y windings over a complete pulse, including off time, is 1,200 amperes; the rms line-to-neutral voltage at peak load is

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The author wishes to thank the University of California Radiation Laboratory staff for the data on the bevatron operating characteristics. He also has used data and some of the figures from "Multiphase Generators and Controls for High-Energy Particle Accelerators," an AIEE conference paper by G. L. Godwin and L. A. Kilgore, and "Ignitron Converters for High-Energy Particle Accelerators," by J. L. Boyer and C. R. Marcum (AIEE *Transactions*, volume 69, part I, 1950, pages 1110–14), for which he thanks the authors as well as for further information obtained by discussions with them.

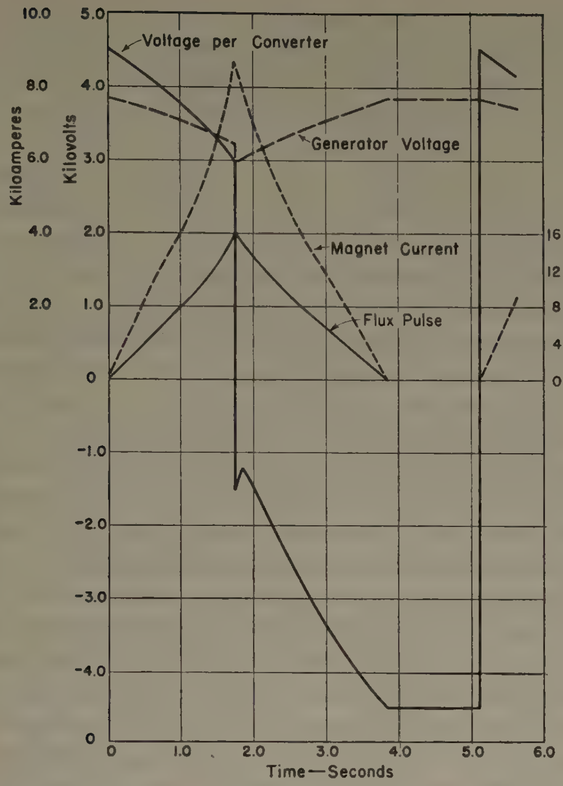


Figure 2. Current, voltages, and flux for a complete cycle

3,200 volts. This gives an output of 11,500 kva per 3-phase Y, or 46,000 kva for each generator. The frequency of 55.8 cycles is somewhat of a compromise, since during a pulse the speed drops from 97 per cent of synchronous speed at its start to about 91 per cent at the peak for the maximum repetition rate. The total inertia of the rotating parts of each complete set is 1,819,000 pound-feet-squared and the stored energy at synchronous speed is 251,000,000 foot-pounds. For a maximum pulse the stored energy given up by each flywheel during current build-up is about 40,000 kilowatt-seconds. This same amount is restored to the flywheel during the current decay and off time.

Each 3-phase Y of the generator is connected to a 6-tank ignitron converter operating as a 3-phase single-way unit with two tanks in parallel through an anode balance coil. The four Y's, each with its converter, are connected in series and, since the Y's are displaced by 30 degrees from each other, this results in 12-phase operation. Since the two generators are not synchronized, the two sets of rectifiers are paralleled through two sets of interphase transformers, with a third set of interphase transformers used to establish a ground point. With the connections shown in Figure 3, the maximum voltage to ground on the d-c circuit is 4,500 volts. The pairs of windings in the figure represent the quadrants of the magnet coils. At no load the direct voltage of each rectifier associated with a Y is 4,500 volts. Thus, in the d-c circuit the voltage to ground varies from +4,500 volts to −4,500 volts and the total voltage across the magnet coils is 18 kv. At peak load this voltage drops to 12 kv and then is changed in two steps to −6 kv for inverter operation. Figure 2 shows the current and voltages for a complete cycle. The off time is one-third the pulse length (75-per-cent duty cycle) so that a complete pulse with off time is about 5.1 seconds (maximum repetition rate of 11.7 pulses per minute).

The generator has an integral-slot full-pitch winding. There were two requirements to be met: the elimination of fluxes due to direct currents in the armature, and a low commutating reactance for satisfactory regulation. To eliminate d-c fluxes due to the armature reaction, it was necessary that there be no net direct current in any stator slot and no net direct current linking the shaft. A normal 3-phase winding meets the condition of no net direct current in each slot, but results in a homopolar field due to the end turns that link the shaft. To eliminate this field two of the Y's are connected with reversed polarity with respect to the other two. This reverses slot currents, but a coil pitch was chosen so that the reversed and unreversed windings are in separate slots. The commutating reactance is a type of subtransient reactance that involves only the phases being commutated at any one time. It can be held to a minimum at high peripheral speed with a well-distributed low-reactance-connected damper winding, and if only one coil side per slot commutates at any one time. The latter requirement is met if a full-pitch winding is used, provided the angle of overlap during commutation does not exceed 60 degrees. Thus a full-pitch winding will meet both requirements. The commutating reactance of the generator is about 21 per cent. The windings had to be given special bracing since the duty is much more severe than in normal use (more frequent faults and periodic load reversals).

The useful part of the pulse is that which corresponds to the current build-up in Figure 2. Since the particles are

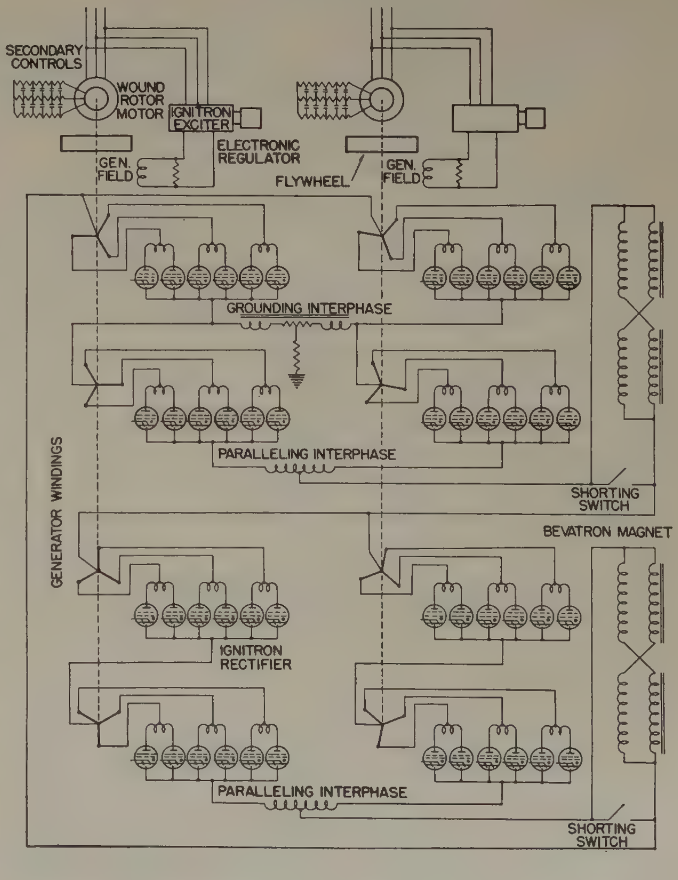


Figure 3. Schematic of the power supply for the magnet

accelerated during this part of the cycle, it is the critical portion and must be duplicated as closely as possible from cycle to cycle. An electronic regulator is used in conjunction with an electronic exciter to return the voltage to the same no-load value during the off time of about 1.25 seconds between each cycle during normal pulsing at the maximum rate.

The ignitron converters were developed especially for this application, which involves unusual loading conditions and inverter operation. The final design was similar to the one that has been proved in 3,000-volt railroad service. The high direct voltage requires the use of four rectifiers in series, and the high peak current requires the use of four anodes in parallel.

When a protective device operates, the stored energy in the magnet must be dissipated by other means than by restoring it to the flywheel. This is done by a short-circuiting switch. Under these conditions the energy will be dissipated as magnet losses. The short-circuiting switch is opened by an air mechanism and latched against powerful closing springs. Protective devices will cause a trip coil to release the latch and the switch will close at high speed (approximately 3 cycles). Simultaneously with this operation the generator field circuit breaker will trip at high speed (approximately 1 cycle) and remove voltage from the circuit.

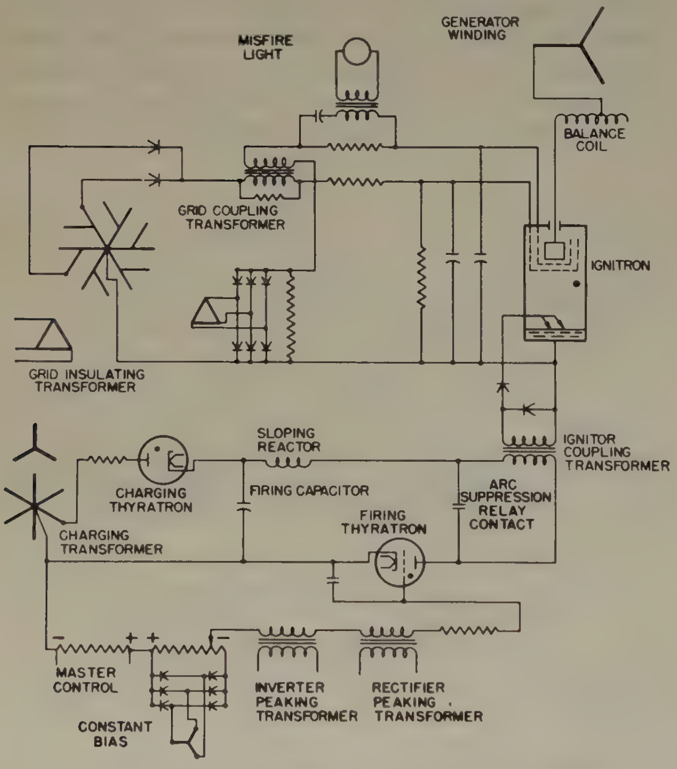

GENERATOR WINDING
MISFIRE LIGHT
BALANCE COIL
GRID COUPLING TRANSFORMER
IGNITRON
GRID INSULATING TRANSFORMER
SLOPING REACTOR
IGNITOR COUPLING TRANSFORMER
CHARGING THYRATRON
FIRING CAPACITOR
ARC SUPPRESSION RELAY CONTACT
FIRING THYRATRON
CHARGING TRANSFORMER
MASTER CONTROL
INVERTER PEAKING TRANSFORMER
RECTIFIER PEAKING TRANSFORMER
CONSTANT BIAS

Figure 4. The excitation circuit for the ignitrons

Surge protective equipment is not shown in Figure 3. It consists of damping equipment to protect against transient voltages and protective gaps. The damping equipment consists of a 1-microfarad capacitor and 90-ohm resistor across each pair of quadrant coils. Three protective gaps are provided for each pair of quadrant coils, one across the coils and one from each end to ground, giving overvoltage protection across the coils and to ground.

The excitation circuits for the converters must have a definite phase relationship with respect to the anode voltages. These circuits are obtained from excitation transformers connected to the generator terminals and are shown schematically in Figure 4. Ignitor firing is obtained from a capacitor triggered through thyratrons. The triggering of the thyratrons is controlled by two peaking transformers in series with a constant negative bias and a positive control bias. The peak voltages from these two transformers are phased so that one triggers the thyratron for rectifier action and the other for inverter action. However, the peak voltage for the inverter peaker is much higher than the peak voltage for the rectifier peaker. Thus, with no positive bias imposed, the negative bias is sufficient to suppress the rectifier pulse peak, while the inverter pulse peak is still sufficiently high to release the thyratron at the no-load inverter firing angle. When a positive bias is impressed, the rectifier pulse peak, which occurs first in time-phase, is no longer suppressed and the thyratron is released at the rectifier firing angle without delay. Rectification will continue until the positive bias is removed, as once the firing capacitor has been discharged at the rectifier firing angle it is not recharged before the inverter pulse from the peaking transformer occurs.

In conjunction with the firing of the ignitors, the grids must be released. The inner grid normally is biased negatively when no current is flowing through the primary of the grid coupling transformer that is in series with the outer grid. The outer grid is energized by two windings of the grid transformer that are 90 degrees apart and phased in such a way that the outer grid will be positive at both the rectifier and inverter firing angles. When the ignitor is fired the outer grid thus will conduct, and a sufficient positive voltage will be induced in the secondary of the grid coupling transformer to drive the inner grid positive. Thus, an ionized path will be established so that the main anode will conduct.

During rectification the magnet current increases rapidly at a nearly constant rate of approximately 4,700 amperes per second, and if rectification were continued the current would reach a high value limited only by the low magnet resistance and the regulation of the power supply. Thus the peak magnet current as used for the pulse is controlled by removing the positive bias when the rated peak magnet current is reached. This stops rectification and introduces inversion automatically to reduce the current to zero. Should the positive bias not be removed in time, a timing relay will remove it automatically when rectification has been allowed for 110 per cent of the normal maximum rectification period. Further backup protection is obtained from inverse time overcurrent relays connected to the current transformers in the generator leads.

In case of an arc-back, instantaneous overcurrent relays connected to the same current transformers will energize a relay that short-circuits the ignitor coupling transformer primary. This suppresses the firing impulse and it is expected that the magnet inductance will reduce the reverse current in the faulty tube to zero in a short time. If this occurs, the instantaneous relay will reset and the short-circuiting relay will drop out, allowing normal operation to be resumed. However, if the short-circuit (arc-back) current is not limited by arc suppression within a few cycles, another inverse time overcurrent relay will cause the high-speed short-circuiting switch to close and the high-speed generator field circuit breaker to trip. Similarly, should an arc-through occur during inversion, the current is limited to the magnet current and will be twice normal current, since the current in the parallel tube will transfer to the faulty one. The tube has a good chance to regain control even with this current, so that there is no instantaneous protection as for arc-backs.

However, should control not be regained within a few cycles, a protective relay will cause the short-circuiting switch to close and the generator field circuit breaker to trip. This relay is connected to a circuit resonant at 60 cycles that is in turn connected across the d-c terminals of each rectifier assembly. For normal operation the relay will not pick up, but when an arc-through occurs and persists there will be a pronounced 60-cycle component in the voltage between the d-c terminals of the particular assembly, and the relay will pick up after time delay.

The typical load cycle (after several at maximum rate) is shown in Figure 5. The top curve is the generator output, corresponding to the magnet currents and voltages shown in Figure 2. The middle curve is the motor-generator set speed and the lower curve the motor input. A master control device applies positive control bias to start rectification. When the magnet current reaches a predetermined value the particles are introduced by an injector into the vacuum chamber at an energy level corresponding to the field at that instant. As stated before this energy level is 10^7 electron volts. As the current increases, the master control device causes the frequency of the accelerating voltage to increase to match the field strength at each instant. Due to the limitations on the permissible variation in system power load, cycling contactors are used in the motor secondary. These cycling contactors operate on a definite time sequence, initiated by the start of each pulse.

In order to limit the power input swings to 3,000 kva total (1,500 kva per set) two cycling contactors, giving three secondary steps, are used. The pulse starts with all secondary contactors energized, but there is a section of permanent slip resistance. When the motor input reaches slightly less than the maximum prescribed kilovolt-amperes, the last accelerating contactor drops out, reducing the input to slightly more than the minimum prescribed input. In like manner the next accelerating contactor is dropped out at the proper instant. When peak magnet current is reached after about 1.75 seconds, the master control device removes the positive control bias and allows inversion to start. At that time the particles have been deflected against the target or outside the vacuum chamber.

Should simultaneous inversion be started on both units, the sudden load reversal could produce high shaft torques at the natural frequency of oscillation. Considerable shaft stresses could result, and when repeated at each pulse would be very undesirable. Consequently, only one-half of the converter units for each generator are changed over to inverters at the end of the rectification pulse. The changeover for the other half is delayed for slightly more than 1 cycle, which corresponds to one-half cycle of the natural frequency of the shaft assembly. In this way the transient torque peak is reduced considerably and inversion of the second half at the proper delay tends to cancel the effects of the first half, so that the tendency to excite the system at the natural frequency is reduced greatly. The change in inversion in two halves causes the notch shown on the upper curve of Figure 5 (actually exaggerated).

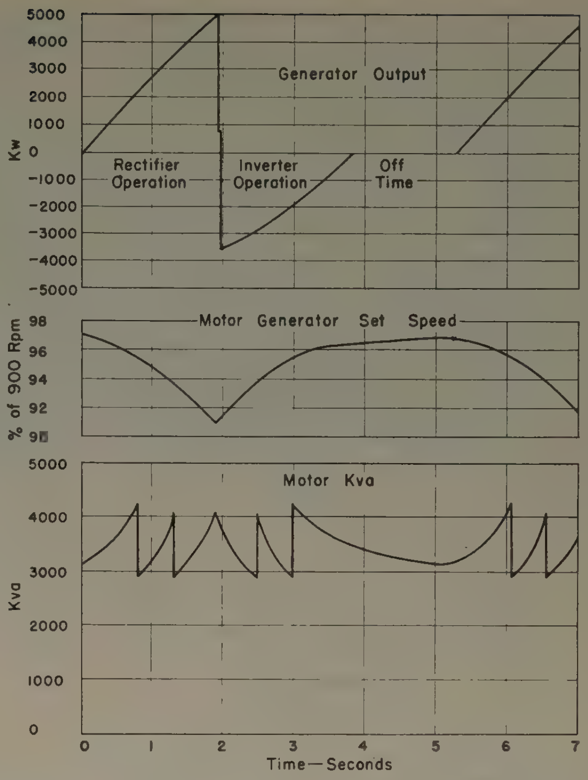


Figure 5. A typical load cycle of the motor-generator sets

An additional precaution was taken by the use of a vibration damper on the generator shaft to make sure that any oscillations due to load reversal will be sufficiently damped by the time of the next reversal to prevent torque build-up. The 2-step inversion is obtained by an internal positive bias that keeps half of the units rectifying after removal of the positive control bias, while allowing the other half to start inverting. This bias is held on for the proper time by means of brushes on a timing commutator on the generator shaft. The spacing between the brushes determines the length of time the bias on a thyratron controlling the internal positive bias will be effective. The spacing between the brushes is adjusted so that the time delay between inversions is one-half cycle of the natural frequency as stated previously.

The stored magnetic energy in the magnet is converted to kinetic energy in the flywheel by accelerating the motor-generator set. The converters operate as inverters to drive the generators as motors and the speed is increased from about 91-per-cent synchronous speed at peak load to about 96.5 per cent in about 2.1 seconds, at which time the magnet current is reduced to zero. During the off time of about 1.25 seconds the motor further increases the motor-gener-

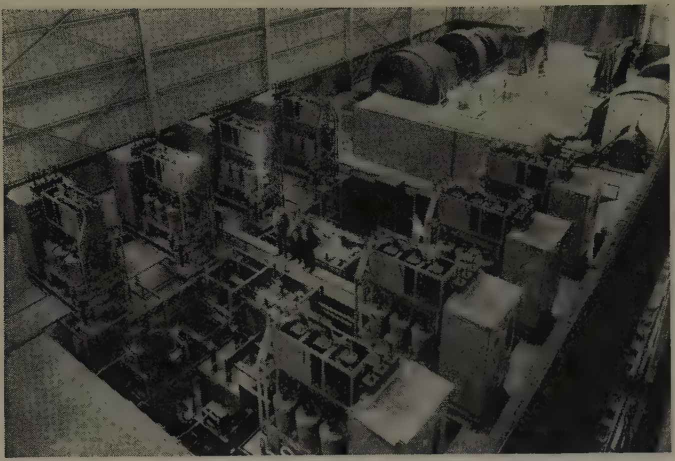


Figure 6. The bevatron powerhouse. The eight ignitron converters and high-voltage excitation units that will operate at 4,500 volts to ground are in the foreground, insulated from ground by post-type insulators. Located in the pit are d-c short-circuiting switches, excitation transformers, and bus structure. In the middle background is the control switchboard for the ignitron circuits, and in the far background on each side are the motor-generator sets

ator set speed to 97 per cent when another pulse is started. The two secondary contactors that were dropped out in time sequence during rectification are picked up in time sequence during inversion to keep the motor input excursion within the specified limits.

At the start of inversion the firing angle must be advanced considerably (about 80 degrees) to have sufficient time at the end of conduction to deionize the tubes. To bring the current to zero as soon as possible and thus minimize the losses, the angle of advance is reduced as the current decreases so that at current zero the advance angle is 30 degrees. This is permissible since, as the current decreases, the overlap angle and the required margin angle decrease, the overlap angle becoming zero at zero current.

The firing angle is adjusted by means of a d-c winding on the inverter peaking transformer. This winding is energized by a constant d-c bias on which is superimposed a variable bias obtained from the rectified anode currents. This variable bias shifts the phase of the peaker pulse proportionally to the inverter anode current and thus automatically adjusts the firing angle as required by the inverter output. As shown in Figure 2, the direct voltage decreases from 18 kv at zero current to 12 kv at the peak current of 8,333 amperes during rectification. It then becomes −6 kv at the start of inversion and increases (negatively) to about −16 kv at current zero. The hump in the inverter voltage curve at the start of inversion is due to the time lag of the inverter peaker phase-shift circuit. During the off time the electronic regulator will adjust the generator voltage so that the next pulse will start again at 18 kv.

To obtain a direct voltage during rectification with the characteristics shown in Figure 2, which results in a nearly linear current characteristic, the generator voltage actually must be given a droop as shown in Figure 2. This voltage characteristic, together with the decrease in magnet inductance as the current increases, results in the substantially linear current build-up curve shown in Figure 2. The generator voltage droop is controlled by the electronic regulator. A d-c bias proportional to generator current is introduced in the regulator to make it regulate for a voltage that decreases as the load increases. The amount of droop is adjustable to obtain optimum operating characteristics.

Since the large amount of stored energy in the flywheel would result in several hours of coasting on shutdown, dynamic braking of the driving motor is used to bring the motor-generator sets to a stop. The electronic exciter is used to excite the motor stator with direct current and the secondary contactors are picked up on a time schedule, resulting in a shutdown time of 5 minutes, which is also the accelerating time for each set. In field tests the actual times were about 6 minutes to start and 4 minutes to stop, but these can be adjusted by proper setting of the secondary contactor control relays.

Many protective features have been included with the apparatus to make the equipment as much self-supervised as feasible. Two types of protection have been provided, one resulting in partial shutdown and the other in complete shutdown. Partial shutdown consists of closing the high-speed magnet short-circuiting switch, tripping the high-speed generator field circuit breaker, and short-circuiting the ignitor coupling transformers. Complete shutdown will result, in addition, in stopping the motor-generator sets by dynamic braking.

Conditions that bring about partial shutdown are: electronic exciter overtemperature, electronic exciter cooling water failure, electronic exciter low filament voltage, converter overtemperature, converter cooling water failure, converter high pressure, excitation filament undervoltage, converter excitation bias undervoltage, converter ground overcurrent, generator field failure, generator overcurrent,

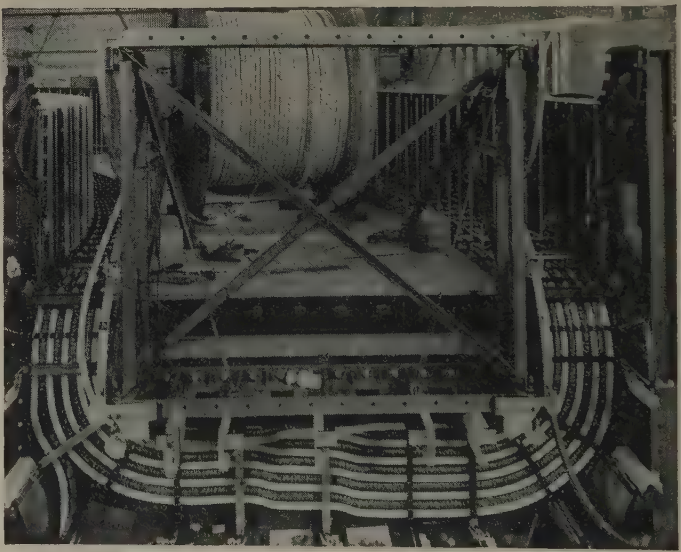


Figure 7. Close-up showing end turns for the field coils of one quadrant of the bevatron magnet as they are being wound. The end turns of this lower section of the field coil bend under the vacuum chamber, thence to the other side. End turns for the upper section bend over the vacuum chamber. Magnetic fields produced by the "over" and "under" end turns cancel each other

magnet coils ground, magnet overcurrent, generator overvoltage, and inversion arc-through (unless self-cleared within a few cycles).

Complete shutdown is caused by: bearing overtemperature, bearing lubricating oil failure, generator overtemperature, motor overtemperature, motor overcurrent, reverse phase, phase failure, undervoltage, and control battery undervoltage.

Figure 6 shows the power plant as it appeared shortly before installation was completed. In the foreground are the ignitron converters and high-voltage excitation units that will operate at 4,500 volts to ground, supported on post-type insulators. Located in the pit are the grounding switch, interphase transformers, excitation transformers, and the bus structure. In the middle background is the control switchboard for generator field and ignitron ignition circuits. In the far background are the motor-generator sets with the motor-control cubicles. The high-voltage switchgear and auxiliary power supply and switchgear are on a balcony to the right.

Figure 7 is a close-up showing the end turns of the lower coil for one quadrant of the magnet. As shown, the end turns for this lower coil bend down. The end turns of the upper coil will bend up in a similar manner. The vacuum chamber will pass through these coils and the magnetic fields produced by the upper and lower end turns will tend to cancel out.

Figure 8 is an earlier picture of the bevatron magnet showing the cable racks in place for winding one quadrant of the coil. It also shows the sectionalized type of core.

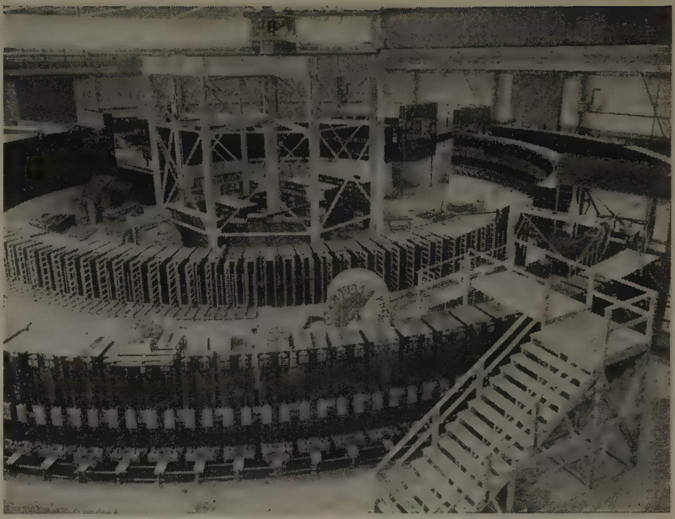


Figure 8. View of bevatron magnet showing cable racks in place for winding one quadrant of the coil

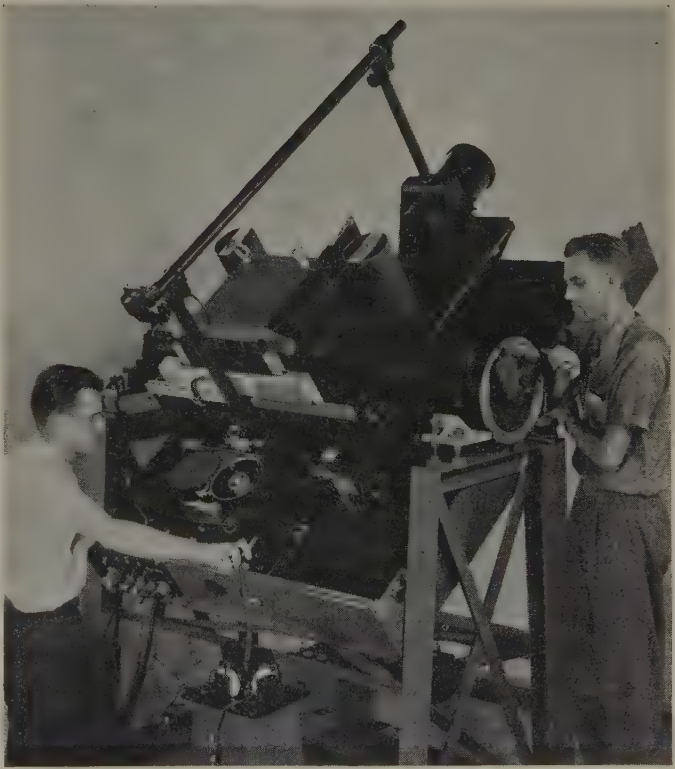
Installation of the electric equipment has been completed and as many tests as could be made without a magnet load have been run with entirely satisfactory results. The bevatron magnet core is complete and the coils will be completed in the near future, but it probably will be some time yet before actual operation can begin.

Giant 35-Millimeter Camera Photographs Aircraft Flight Path

Perhaps the largest 35-millimeter camera ever built is this 1,500-pound research instrument, known as a target-angle recorder. Built by Beckman and Whitley, Inc., San Carlos, Calif., and designed to expose 10 frames per second over a period of 2 minutes, the unit is to be used in United States Naval Ordnance test center studies of aircraft flight path and diving-angle variations.

The camera is aimed at the aircraft by means of the gunsight tube on top. By keeping the diving craft on the crosshairs of this sight with a control stick, the operator moves the film drive mechanism and shutter assembly over the area of a large graticule whose rulings and index numbers appear on the finished pictures. These pictures then can be analyzed to provide data on the precision with which the dive is made. As the tests proceed, live bombing runs will be made on the recorder. During this period, aiming will be done over a television circuit, the recorder having provisions for a tv camera to mount behind the gunsight.

Crosshair motion is provided by the control stick which is visible in the operator's right hand. This complete control box can be located at the remote point where the television picture tube is placed.



Basic Structural Design for Transmission Substations Including Light Metals

AIEE COMMITTEE REPORT

A classification of structures for transmission substations is given, with recommendations for choosing suitable materials and designs. Methods of determining design loadings are discussed, together with industry practices regarding design and fabrication standards.

TRANSMISSION substation structures, for the purpose of this report, are considered to be those associated with voltages of 115 kv and higher.

Transmission substation structures may be classified as to general type into four principal categories, depending on whether the station makes use primarily of a number of isolated structures, or of a large interconnected structure of latticed columns and girders; and depending on whether the principal bus work consists of rigid conductor or cable under tension. While cost is an important factor, over-all cost differences between different types of design are usually relatively small. Therefore, other factors, such as space requirements, appearance, and adaptability to standardization, may be decisive. Any common one-line scheme of bus layout can readily be accommodated with any of the general types listed.

Transmission substation structures may also be classified as to the material used. Galvanized steel is and will probably remain the predominant material. There are applications, however, where painted steel, aluminum, wood poles, structural timber, and even reinforced concrete may be used. Determining factors in the choice of material include cost (first cost and cost of maintenance and operation), availability of material, resistance to corrosion, resistance to fire, life expectancy, appearance, size of revenue-producing load served, and whether installation is temporary or permanent.

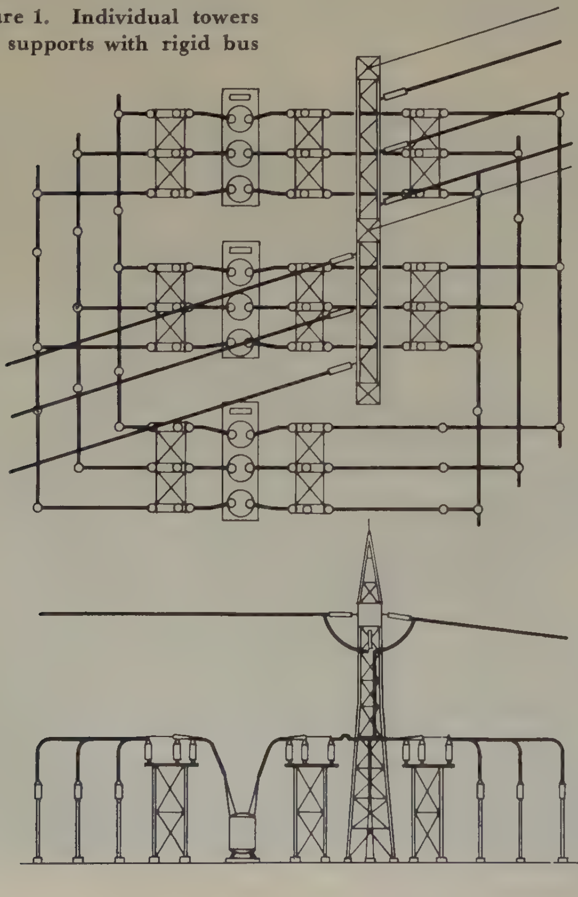


Figure 1. Individual towers and supports with rigid bus

Aluminum has been used to meet severe corrosion conditions. Where these conditions do not exist, it generally has been unable to compete with galvanized steel under conditions of price and availability heretofore existing, except in the case of voltages below the scope of this report.

A high degree of design standardization is possible in the design of structures, and has been of tremendous benefit to utilities which have made the fullest use of it.

Methods of determining design loading are discussed, together with industry practices regarding design and fabrication standards.

GENERAL CLASSIFICATION OF STRUCTURES

ACCORDING TO THIS classification, substations fall into two main categories, depending on whether the design provides basically for a large interconnected assembly of latticed columns and trusses, or whether a number of individual structures are used, interconnected only by the electric lines and bus work.

Within each of these two categories, variations exist depending on whether the principal bus work consists of rigid conductor such as pipe, or flexible cable under tension.

The principal characteristics distinguishing these various general types of design are as follows:

A1. Individual Towers and Supports, Rigid Bus. Incoming and outgoing lines are dead ended on high structures, consisting of wide base towers connected by box trusses at the top. These structures can be used singly (two towers and one connecting truss per line) or combined in multibay arrangements, which result in a saving in the number of tower elements.

Full text of paper **52-21**, "Basic Structural Design for Transmission Substations Including Light Metals," recommended by the AIEE Committee on Substations and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 21, 1952.

This report was prepared by members of project number 8 of the AIEE Committee on Substations. Personnel of the project are: R. F. Stevens, *sponsor;* M. K. Brown, H. F. Gidlund, K. B. Hoffman, E. M. Hunter, D. C. Millard, J. H. Rixse, Jr.

Disconnecting switches are usually supported on separate low structures, one per 3-pole switch.

Bus of rigid pipe is supported by disconnecting switch insulator stacks and apparatus bushings, and by bus insulators or insulator stacks which are in turn supported on low structures or individual pedestals (see Figure 1).

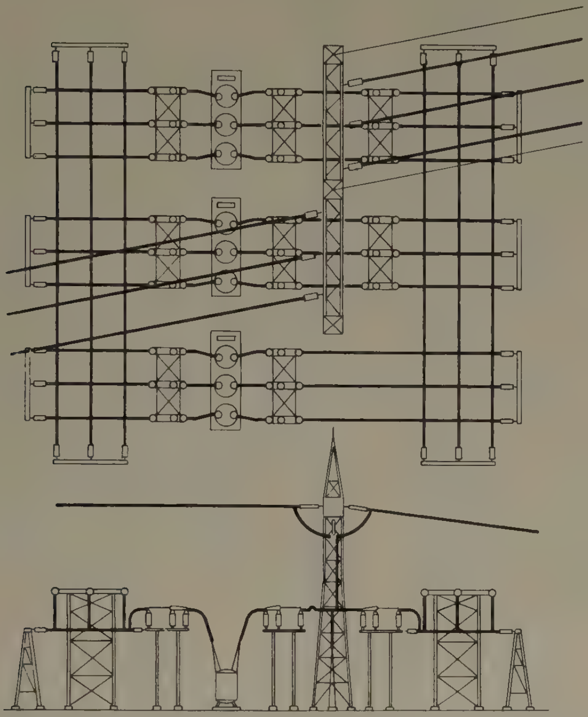


Figure 2. Individual towers and supports with strain bus

A2. Individual Towers and Supports, Strain Bus. Lines are dead ended and disconnecting switches are supported in the same manner as above.

Bus is of flexible cable conductor, dead ended between high or medium-high dead-end structures. Intermediate support is provided, if necessary, to prevent excessive sag, by suspension insulators attached to appropriate overhead structures, or bus insulators or insulator stacks supported on lower structures or pedestals (see Figure 2).

B1. Latticed Columns and Trusses, Rigid Bus. The substation structure is made up of interconnected square or rectangular latticed columns and box trusses. Columns are usually of narrow base design, except where a wide base is needed to give lateral stability to resist heavy line pull-off tensions. Incoming and outgoing lines are dead ended on appropriate trusses of the structure. Disconnecting switches are usually mounted on trusses of main structure.

Bus is of rigid pipe, supported by bus insulator stacks, which in turn are supported by trusses of the main structure (see Figure 3).

B2. Latticed Columns and Trusses, Strain Bus. Lines are dead ended and disconnecting switches are mounted as in B1. Bus is of flexible cable conductor, dead ended between structures at opposite ends. Intermediate support is provided, if necessary, to prevent excessive sag or to maintain clearance, by suspension insulators or bus insulator stacks which are supported in turn by trusses at intermediate points in the structure (see Figure 4).

General Design Types Using Other Materials. The descriptions given apply primarily to steel (or other metal) structures. Guyed wood poles can be used, however, in the case of the first or rigid bus scheme (A1) for dead ending of lines, or in the case of the second scheme (A2) for dead ending of both lines and busses. Wood pole and timber structures (the counterpart of the steel structures described under B1 and B2) are sometimes used at 115 kv, but the size of the necessary timbers generally makes this type of construction somewhat impractical at higher voltages. The same comment applies to wood structures of fabricated sawed timber members.[1]

FACTORS INFLUENCING CHOICE OF GENERAL TYPE

Cost. While cost is an important factor, its effect should not be overemphasized. The elements of a station affected by structural design (primarily steel, bus, and insulators) may be of the order of 5 to 10 per cent of the total cost. If the net difference in total cost of these elements for different types is, say, 10 per cent, then the choice of basic design type will not affect the total cost more than 0.5 to 1.0 per cent. Thus, such factors as personal judgment as to relative appearance and convenience for operating and maintenance, rather than cost, may well determine the choice.

So far as cost is a factor, it tends to favor the column and truss design at distribution voltages, and to favor individual tower designs increasingly as higher voltages (with the necessary higher structures and wider bay spacings) are

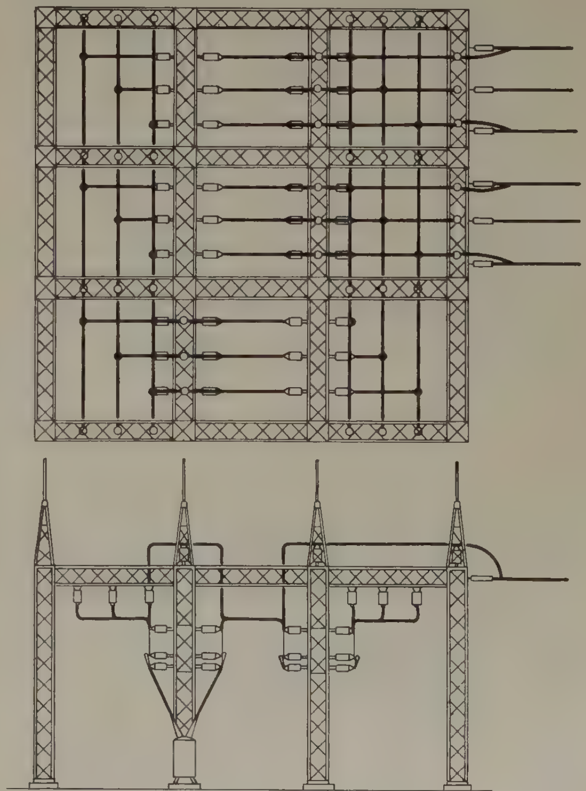


Figure 3. Latticed columns and trusses with rigid bus

considered. For such voltages, the individual structure design (especially in the rigid bus form) is by far the most economical in use of steel, though this saving is partly offset by more expensive insulators and bus work, and by the generally more expensive multiple foundations.

Space Requirements. The latticed column and truss design is somewhat more compact. There is, in fact, a strong incentive to make it compact to decrease the length of connecting girders and thus the cost of the steel structures. Particularly in cases where the voltages are low enough to permit vertical-mounted disconnecting switches, important space savings can be made. The importance of this factor depends, of course, on location. It may be extremely important in urban areas, but in the rural areas, where high-voltage switching stations are built, large sites may be available and the cost of land may be a relatively insignificant item.

Appearance. While appearance is largely a matter of individual judgment, most engineers would probably rank the individual structure, rigid bus design, high in simplicity, straightforwardness, and attractiveness of appearance.

Most engineers would consider the appearance of the individual-structure strain bus design as acceptable, though perhaps not quite as good as the design using rigid bus.

The latticed column and truss designs in general are quite neat though somewhat massive in appearance.

Earthquake Shock. This factor usually need not be considered but may be important in some areas. Certain utilities have suffered earthquake damage and have adopted the strain bus designs on new construction for this reason, but have not felt it worthwhile to replace rigid busses in existing stations. It is by no means certain that the latter type of bus cannot be designed so that its resistance to earthquake damage is adequate.

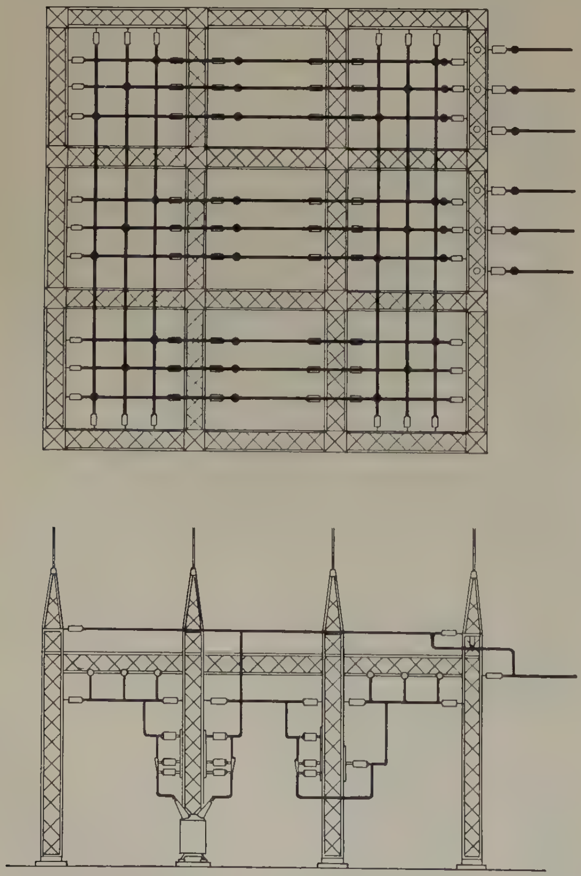


Figure 4. Latticed columns and trusses with strain bus

Standardization. The individual structure designs, whether used with rigid or strain bus, lend themselves especially well to standardization and the stocking of standard structures. However, a high degree of structural standardization can also be obtained with column and truss designs if bay dimensions and structure heights are standardized on a system-wide basis.

One Line Diagram. Contrary to what might be supposed at first thought, the one line diagram selected usually has little or no effect on the choice of general type of structure, though it does of course affect the arrangement of structural elements.

Much work and standardization of these elements has been done by utilities and manufacturers, and it almost invariably will be found that different arrangements of standard structural elements will meet better than 95 per cent of the requirements of any practical one line diagram which might be considered.

CLASSIFICATION BY TYPE OF MATERIAL USED

SUBSTATION STRUCTURES have made use of a wide variety of material including steel, aluminum, structural timber, wood poles, and, for very limited purposes, reinforced concrete.

Factors influencing selection of material include: first cost of material, cost of erection, cost of maintenance, availability of material, resistance to corrosion, freedom from fire hazard, life, appearance, size of revenue-producing load served, and temporary or permanent nature of structure.

A. Steel. By far the greater number of high-voltage permanent substations make use of steel structures. The structures have long life, neat appearance, and are not inflammable. The grade of steel used in substation structures by most utilities is the ordinary structural grade, although high-strength steel such as is used on transmission lines is occasionally specified for substation structures. The surface may be painted, but galvanizing is far more common and more permanent. The service requirements at many stations often make repainting impractical in the vicinity of live parts, though this factor is less important for transmission substations than for lower voltage stations where the clearances are less. Nevertheless, there is still a large margin, mainly economic, in favor of galvanizing. Some utilities use aluminum paint on both equipment and structures, partly as a matter of appearance.

The most common type of connection is a bolted connection, since assembled structures are usually too large to galvanize after welding or riveting. However, small plates, clip angles, and so forth, may be attached to other members by welding prior to galvanizing. Some utilities make extensive uses of trusses or subassemblies of various kinds, of a size small enough so that they can be galvanized

Table I. Galvanized Steel Station Structures

Typical Specification Requirements

	Unit Stresses				
		AISC			
	NEMA	Utility A	Utility B	Utility C	Utility D
Tension, net section	20,000	20,000	24,000	20,000	22,000
Tension, net section bolts	20,000	18,000	15,000	20,000	22,000
Compression, $\frac{l}{r}<150$	$\frac{18{,}000}{1+\frac{l^2}{18{,}000r^2}}$	$17{,}000-0.485\frac{l^2}{r^2}$*	$24{,}000-100\frac{l}{r}$	$18{,}000-0.485\frac{l^2}{r^2}$	$22{,}000-98\frac{l}{r}$****
Maximum	16,000	17,000	19,000		16,600
Compression, $\frac{l}{r}>150$	$\frac{18{,}000}{1+\frac{l^2}{18{,}000r^2}}$**	$\frac{18{,}000}{1+\frac{l^2}{18{,}000r^2}}$	$\frac{202{,}000{,}000}{\frac{(l)^2}{r}}$	$\frac{22{,}500}{1+\frac{l^2}{18{,}000r^2}}$	$15{,}400-54\frac{l}{r}$*****
Bending, tension	18,000	20,000	24,000	20,000	20,000
Compression (no deflection)	18,000	20,000	24,000	20,000	20,000
Where $\frac{l}{b}>10$	$\frac{20{,}000}{1+\frac{l^2}{2000b^2}}$***		$28{,}000-400\frac{l}{b}$	$\frac{20{,}000}{1+\frac{l^2}{20{,}000r^2}}$	...
Shear on unfinished bolts	12,000	15,000	13,000	15,000	15,000
Bearing on unfinished bolts	24,000	24,000 (SS)	26,000	24,000	30,000
Wind load, pounds per square foot	25	30	15	15	20
Ice	2×weight of steel	1/2 inch	1/2 inch	2×weight of steel	
Max. *L/R*, legs and main columns	150	120	135	150	150
L/R secondary	200	200	180	200	200
L/R redundants	220	250	200	220	225
Unsupported length, crossed and bolted at center	100 per cent	for X-axis end to end	75 per cent end to end		Z-axis intersection to end X-, Y-axis end to end
Unsupported length, braced one way	100 per cent	for X-axis 100 per cent end to end	85 per cent end to end		Z-axis 70 per cent end to end X-, Y-axis end to end
Washers under each nut	none	none	3/16 inch	none	3/16 inch
Nuts	square	hexagonal, recessed	square	hexagonal	hexagonal
Tower footings, factor of safety overturning	1.5	1.5	1.5	1.5	1.5

* $\frac{l}{r}>120$, ** $\frac{l}{r}>120$, *** $\frac{l}{b}>15$, **** $\frac{l}{r}<150$, both legs connected, ***** $\frac{l}{r}<200$, one leg connected, maximum, 12,700.

after welding. While these techniques are particularly applicable to distribution substations, they have been successfully used for transmission substation structures by bolting a number of welded and galvanized trusses together to form long box trusses and columns.[2,3,4]

Fabrication or welding of parts previously galvanized is, of course, impossible without damage to the galvanize coating, and although such supports may be touched up with paint, a point of weakness remains. Occasionally some utilities use this method, which has some advantage in first cost, but its use is not common.

Structures are commonly shipped knocked down and assembled at the site, although high structures are frequently assembled in whole or part on the ground at the site and then uprighted.

B. Aluminum. Galvanized steel racks have been so satisfactory, and the first cost of this material has been so much less than aluminum, that utilities have had little incentive to consider the use of the latter for general application.

Moreover, the inherent lack of stiffness has been a distinct disadvantage for aluminum. In substation structures, a minimum amount of diagonal bracing is usually desirable to avoid interference with electric leads. This results in the desire to use as great an unsupported length as possible in many compression members, and in this respect, aluminum is at a disadvantage as compared to steel.

Nevertheless, aluminum has advantages which have led to its selection in a number of cases, and its use might conceivably be extended in the future if it should become available in quantity at a price more favorable in relation to steel.

Principal, and possibly the only, applications to transmission substations in the past have been in contaminated atmospheres of a type that would corrode galvanized steel rapidly but leave aluminum relatively unaffected. Here initial cost has been a secondary factor.

In addition, aluminum has been used by utilities and manufacturers for subtransmission and distribution substations usually of 33 kv and below, even when corrosion of galvanized steel is not a factor. Though these fall outside the scope of this report, a discussion of the reasons favoring the use of aluminum for such purposes may be pertinent. In these cases, aluminum was price-competitive for two reasons: because of its light weight; and because it did not require a protective coating.

The light weight made it possible to assemble relatively large structures and subassemblies under factory or shop conditions, and transport them to the site and erect them cheaply.

The nature of the material permitted assembly by welding without damage to a galvanized coating or the necessity of subsequent painting. On this basis, in certain parts of the country, contractors using aluminum structures have sometimes been able to underbid those using steel, on the basis of structures erected in place for voltages of 33 kv and less.

Similar advantages have led various manufacturers in the past to supply aluminum structures as standard components of "packaged substations" in subtransmission and distribution voltages.

Aluminum alloy *61S-T* is most commonly used.[5,6]

Some very preliminary study has been given by aluminum companies and utilities to the use of aluminum in substation structures for transmission voltages, to see if it could be justified on a cost basis where unusual corrosion conditions do not exist. However, under present relative cost conditions and using present design techniques, there is little apparent advantage over structural steel.

On the basis of unit stresses proposed by some of the aluminum companies,[5] the cost difference would not be great though the cost for aluminum would be higher. However, use of these recommended stresses would involve considerably lower safety factors than those commonly used by utilities in steel structure design.

Most of the aluminum substation structures built heretofore have followed the same conventional design practices used for steel structures with members consisting of rolled (or extruded) angles, channels, I-beams, and plates bolted or welded together. On this basis, and using comparable safety factors, material cost for aluminum has invariably been greater than for steel.

In the case of the cost erected, the difference will be less, since savings can be shown in cost and manpower for fabrication, transportation, and erection. Because of the lighter weight, it more often will be feasible to complete subassemblies in the shop, rather than in the field; and to complete larger assemblies on the ground rather than in the air. Because galvanizing is not required, many aluminum joints can be made by welding rather than bolting. Nevertheless, this will probably decrease rather than eliminate the cost handicap of aluminum.

Another avenue of approach might be to investigate the use of different structural shapes. A tubular column, for instance, makes more efficient use of material in compression than an angle or channel. Perhaps use of such a shape might be investigated since in the case of aluminum there need be no concern about corrosion from the inaccessible inside surfaces. With members of this type, the design of inexpensive joints is more difficult, and it is not certain whether any saving in over-all cost could be realized by use of such members.

If the first cost differential cannot be eliminated, it then becomes necessary to determine whether any conditions may justify paying a premium. Two advantages of aluminum may be cited in this respect:

1. Longer life than galvanized steel under normal atmospheric conditions. Since the life of a galvanized structure is probably as much as 50 years, this advantage is not too impressive, but it may be given some weight.
2. Appearance may be slightly better.

C. Wood Pole. Use of wood-pole structures for 115 kv is not uncommon in some parts of the country. This construction is sometimes used, though more rarely, for even higher voltages. At higher voltages the clearances and stresses require poles and timbers of a size that is harder to procure.

Wood-pole design has the advantage of low first cost and (in normal times) quick availability of materials. Disadvantages include relatively poor appearance, high maintenance, shorter life, and necessity for heavy and unsightly guying. As a result, it is better suited to temporary construction or to emergency jobs where there is no time to wait for design and fabrication of steel structures.

Crossarms used with wood-pole structures have the tendency to sag, buckle, or twist as they become wet or dry out. It is sometimes difficult for this reason to maintain alignment of certain types of equipment such as disconnecting switches.

D. Structural Timber. Very neat racks can be made with structural timbers, which also have a reasonably long life when properly treated. Much progress has been made in the development of connectors for joining members of structures of this type. During the last war, when steel became extremely scarce, many such structures were built and have operated successfully.[1] Later, structural timbers, and especially metal connectors, also became scarce so that use of this type of design was largely stopped. Structural timber makes a generally satisfactory rack, though it is less permanent and probably less pleasing in appearance than racks made of steel. It has the additional disadvantage that it is not fireproof.

E. Reinforced Concrete. Reinforced concrete in high-voltage switchyard structures is usually limited to footings. Reinforced concrete may be used for pedestals to support high-voltage busses, or for high-voltage disconnecting switch supports, but this is not at all common.

DESIGN LOADINGS

CERTAIN BASIC DATA are required by the structural designer, including the following:

Conductor Tension. It is necessary to determine first whether the substation dead-end structure will be required to resist the full maximum tension for which the transmission line is designed, or whether the line will be dead ended just outside of the station, and connected thereto by a "slack span" of considerably lower design tension.

If the station dead-end structure is outside the station bus, it will probably be satisfactory and frequently more economical in total line plus station cost if the station structure is designed for full line tension, thus eliminating one transmission line dead-end tower. If the transmission line must pass over a main bus to reach the station dead end, then safety considerations may dictate a separate dead end on the first line tower, in which case the substation structure can be designed only for slack span tension, with some saving in steel.

The maximum design tensions for such transmission line slack spans, and of strain busses within transmission substations will, in practically all cases, be within the range from 1,000 to 5,000 pounds. Such tensions provide a conservative loading for a single string of standard 10-inch insulators and avoid the complication of double insulator yokes, as well as the expense of unnecessarily heavy dead-end structures.

Actual tension used depends on size of conductor, span length, and spacing of intermediate suspension or post insulator supports, if any. Design tensions will generally be chosen so that the conductor is sufficiently taut to present an acceptable appearance at all normal temperatures.

Differential expansion of structure and bus may have to be considered. In extreme cases, springs may be used if the range in tensions would otherwise be too great.

Line Pull-Off Angle. The designer must know the maximum angle (relative to a line perpendicular to the structure) at which conductor tension may be applied. By proper location of lines, this theoretically could be made 90 degrees in all cases. However, for little, if any, additional expense, standard substation dead-end structures can be designed to resist the assumed maximum conductor tensions at angles up to 10 or 15 degrees from the perpendicular. One utility designs its standard structures for pull-off angles up to 30 degrees.

To provide additional flexibility without appreciable increase in cost, most dead-end structures are symmetrically designed; that is, conductors may be dead ended on either face of the truss.

Equipment. Structures should be designed to support any equipment which may be mounted thereon. An additional margin is desirable to permit some flexibility in the make, type, and perhaps the capacity of the equipment which can be accommodated. This permits standardized structural elements to be used under slightly different conditions in different applications and allows for possible future changes.

Ice and Wind Loads. Minimum values to be assumed may be fixed by statute for a particular locality, in some cases by reference to the National Electric Safety Code.[7] Suggested values are also given in the standards of the National Electrical Manufacturers Association.[8] The designer will, of course, wish to set higher values where unusually severe icing and wind conditions exist.

Short Circuit. Structures must be adequate to resist any short-circuit stresses which may be transmitted to them from the busses.

Earthquakes. These are a practical problem only in portions of the country, where the incidence of severe earthquakes is high (Zone 3 as established by the United States Coast and Geodetic Survey, and to a lesser extent, Zone 2). The problem is a complex one. Damage is probably determined as much by soil, water table, and subterranean structure at the site as by the severity of and distance from the original disturbance.

One large utility which formerly used a great deal of rigid bus, lost such a bus during a severe earthquake at a station which was located almost on top of the earthquake fault. As a result, this company adopted a strain bus design for stations built subsequently, though no program of general replacement at older stations was undertaken.

On the other hand, rigid busses have successfully withstood severe earthquake shocks at other locations, and further study may be warranted on the vulnerability of a well designed rigid bus when subjected to this hazard.

In areas where it is thought advisable to design for lateral stresses due to earthquakes, a value such as 0.2 g. is usually considered adequate.

ALLOWABLE DESIGN STRESSES

The National Electrical Manufacturers Association has developed a standard for structural designs which is in use at the present time by its members and by many utilities.[8]

A standard much used by the steel industry as a whole, that of the American Institute of Steel Construction,[9] is also used in substation design.

There seems to be little uniformity in the utility industry at present, however. Reports from a small sampling showed that no two of those reporting used exactly the same standards throughout, though the actual differences for the most part were not too large or significant.

Unless there is an important reason to the contrary, it would seem advisable to use one of the generally recognized standards, if only because shop detailing at the factories will proceed more rapidly and smoothly if the detailers are following a standard with which they are familiar.

DESIGN STANDARDIZATION

Standardization of steel structures has many obvious advantages. Design and fabrication costs are decreased. It becomes feasible to stock certain standard towers, bays, or panels so that a station can be extended or a new station built on very short notice. Such standard structures should be built with sufficient flexibility or design so that they can be used to mount equipment of various different ratings and makes.

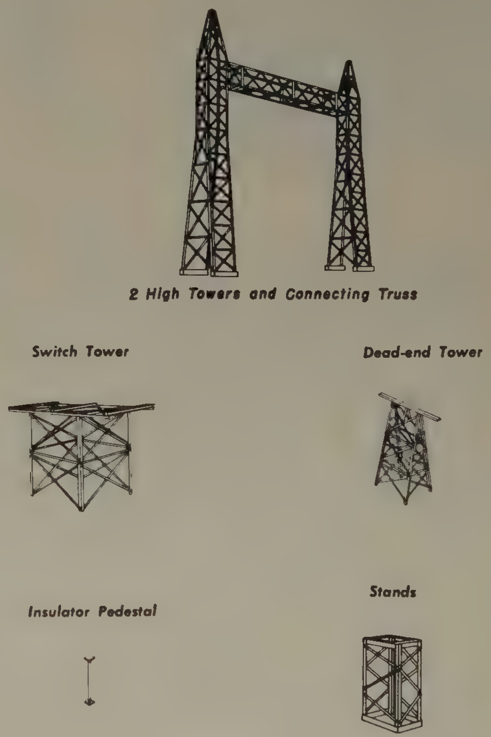


Figure 5A. Individual tower-type structures

While exact duplication between stations is uncommon in the case of transmission substations of 115 kv and higher, most utilities find it expedient to build such stations as an assembly of individual bays or units which are themselves highly standardized as between bays in a given station, and as between different stations.

When this is done, steel can be diverted readily from one

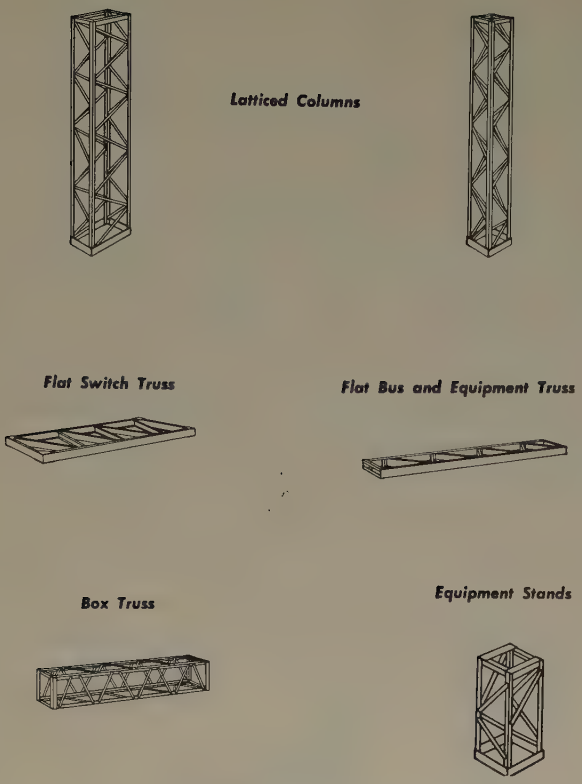


Figure 5B. Latticed column types for structures

station bay to another or from one station to another if conditions change without expensive refabricating and without changing station design or relocating footings. Use of the same shop details on different steel orders results in corresponding members or assemblies being interchangeable even though purchased from different suppliers.

Many of the power utilities and some of the manufacturers have developed sets of standard "building blocks" which have been found suitable for meeting by far the greater part of their structure requirements, leaving only a small percentage of the structure tonnage which must be designed as special structures. See Figure 5.

Materials Specifications. Typical specifications used by utilities for steel include American Society for Testing Materials Designation A7[10] as amended to date, and Federal Specification number *QQ-S-741*, type *II*, grade *B*, class *I*.[11]

Marking. Permanent and legible marking of steel (or aluminum) members is important. A common practice is to mark the members with a metal die (before galvanizing) in the case of galvanized steel. Marks should be near the end or ends on what will be an outside face of the member. In addition, it is usually desirable to repeat the marking with a painted stencil mark of bright color paint near the stamped mark for more ready identification in material handling and erection.

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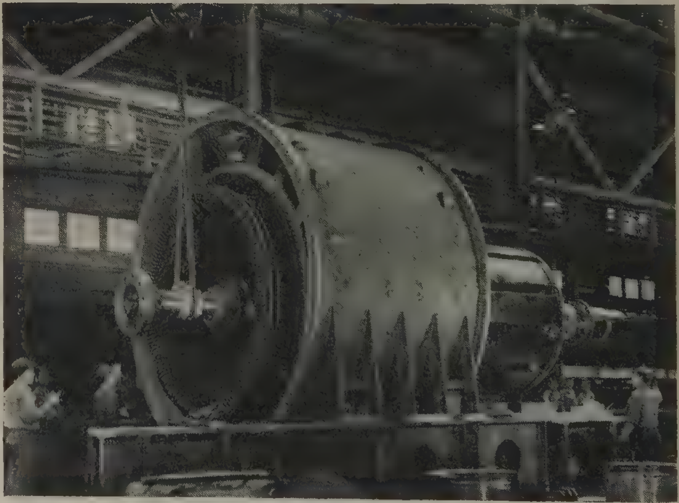
Threading a Giant Needle



A clearance of less than 5/8 inch between the rotor and the inside of the stator section of this 50,000-kva hydrogen-cooled synchronous condenser makes the assembling operation shown here a delicate one. Being built by General Electric's Large Motor and Generator Division at Schenectady, N. Y., the 90-ton rotor is guided carefully into place by two overhead cranes.

Phase-Comparison Carrier-Current Relaying System

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SINCE ITS INTRODUCTION 6 years ago, phase-comparison relaying has enjoyed wide acceptance. As originally conceived, its field of application was to be largely for medium-length, 2-terminal overhead lines. The operating experience has been so good that the demand has grown for extending its field of application to longer lines, to 3-terminal lines, and to certain cables. Also, its inherent immunity to the effects of mutual inductance makes its use attractive for ground-fault protection even though it may not be applicable for phase-fault protection. In such cases, there was a need to combine the virtues of phase- and directional-comparison relaying. Modifications now have been made to phase-comparison relaying equipment that will provide these desired extensions of its field of application. See Figure 1.

Phase-comparison carrier-current relaying consists basically of the comparison by means of a carrier-current channel of the phase angles of the line current entering and leaving a protected section.

Improvements in the new relaying terminal are obtained by modifications in both the carrier-current and relay equipment. In particular, the carrier-current equipment now has special provisions in the transmitter to reduce harmonic radiation and a receiver of greater selectivity. The relay equipment uses appropriate circuitry to obtain square waves from the single-phase sinusoidal signal derived by means of a negative sequence network from the 3-phase line currents. This square-wave output operates two levels of fault detection, a low set fault detector which starts carrier and a high set fault detector which places the relay in its tripping position. The transmitter is driven by the square wave with resulting higher power output. Improvements due to the modification made in the new relay terminal are

1. Positive operation is assured on transmission lines with attenuations up to 35 decibels. This permits operation over longer lines and over certain cables.
2. Improved selectivity and reduction of harmonics in the carrier-current equipment allow more channels in the available frequency spectrum.
3. Provisions are incorporated in the equipment for its combined use with directional-comparison equipment. This provision is for medium and longer length lines where directional-comparison relaying may be used to advantage for phase relaying while, because of mutual inductance with parallel lines, phase-comparison relaying will be required for ground faults.

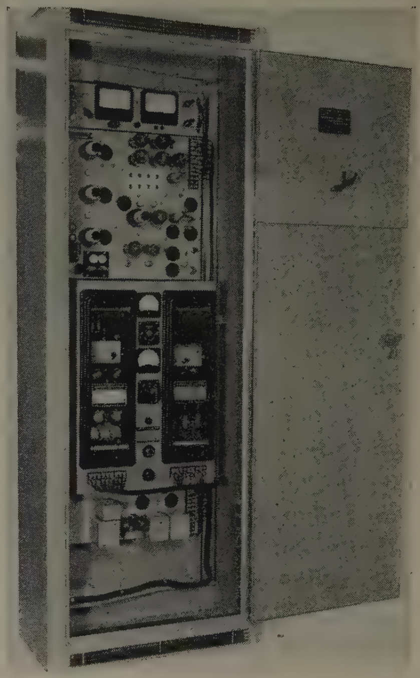

Figure 1. Phase-comparison carrier-current relaying terminal equipment. Top unit: carrier-current test equipment; second unit: carrier-current transmitter receiver; third unit: relay unit; bottom unit: carrier-current voice modulator

4. Two adjustable levels of fault detection may be used to compensate for a possible 2-to-1 ratio of fault current magnitudes between the ends of a 3-ended line, making the equipment applicable to some 3-ended lines.
5. Higher speed of operation is obtained at lower values of fault current than with the superseded equipment. An operating time of less than 2.5 cycles on a 60-cycle basis is obtained at just above pickup. The operating time averages less than 2 cycles at a value of fault current of four times pickup current.
6. The equipment is designed for use with vacuum tubes which are either pretested to eliminate early failures or are a long-life type. However, the equipment will operate unimpaired with standard receiving-type tubes.
7. Minimum relay pickup is independent of the load imposed by the carrier-current transmitter on the power amplifier of the relay equipment.
8. The carrier channel equipment is available in two frequency ranges, covering a wider range of channel frequencies.
9. A phase shifter is incorporated to compensate for time of propagation between terminals of long transmission lines.
10. The carrier set is arranged so that it may be converted for directional-comparison operation by exchanging a small subpanel on the front of the equipment.

Latest power and electronic techniques have been applied to obtain equipment superior in quality and performance to the superseded carrier-current phase-comparison relaying equipment. This system uses the highly desirable features mentioned to assure high-speed transmission-line relaying that is easy to apply, simple to maintain, and reliable in operation.

Digest of paper 52-52, "A Phase-Comparison Carrier-Current Relaying System for Broader Application," recommended by the AIEE Committee on Relays and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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Improved Cathode-Ray Tube for Application in Williams Memory System

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Design features and electrical characteristics of a new cathode-ray tube which was developed specifically for electrostatic storage applications are described. Particular attention is given to the spot size, deflection defocusing, "spill" characteristics, screen blemishes, signal output, and the compromises made to achieve optimum over-all design.

THE WILLIAMS[1] scheme of electrostatic storage is being widely used in a number of the large-scale digital computers now in use or under construction. While improvements have been made by proper choice of tube operating parameters, better geometric layout of the array of spots, and by circuit refinements, many of the ultimate limitations on storage capacity and on the permissible number of references per regeneration of nearby spots lie in the cathode-ray tube itself.

Some of the basic characteristics desired in an electrostatic storage tube are similar to those sought in a conventional oscillograph tube. However, since the design of any cathode-ray tube involves a specific set of compromises calculated to achieve the best over-all performance in a particular application, it has been possible to make very significant improvements in storage operation by simply tailoring the characteristics to fit the application at hand. The *IBM-79** is a 3-inch cathode-ray tube which has been developed along these lines.

The choice of a 3-inch diameter tube was based largely on considerations of economy of space. While it is true that more total bits† may be stored in a larger diameter tube, the gain is not at all comparable to the increase in target area. When comparisons are made in terms of bits stored per unit tube volume—and this is probably the most realistic evaluation, especially for a commercial machine—the gain in space efficiency of a 3-inch tube over, say, a 7-inch tube is approximately 250 per cent. Figure 1 shows an *IBM-79* tube. The over-all length of $13^3/_4$ inches is somewhat greater than that of usual 3-inch tubes to accommodate a lower magnification gun and a longer deflection plate structure. Figure 2 shows the gun structure. Figure 3 shows a packaged storage unit consisting of two *IBM-79* tubes, a signal amplifier, and associated circuits for sensing, regeneration, and switching. In this application, each tube stores 1,024 bits in a rectangular, hexagonally packed array.

TUBE DESIGN AND PERFORMANCE

Information Density and "Spill" Characteristics. Probably the most important characteristic of any given tube is how many bits of information may be stored on the target. The question of storage capacity is intimately related to a large number of operating conditions connected not only with the tube itself but also with the entire plan of read, write, and regenerate operations for a particular machine. As is well known, for example, the permissible spot density is influenced very markedly by the number of times it is required to operate on certain spots before adjacent spots are read or regenerated. Further, the storage capacity depends on the particular refilling technique employed—for example, dot-dash, circle-dot, defocus-focus, and so forth—and on the geometric layout of the array. To divorce actual tube performance as completely as possible from machine complexities, the following simple spill test has been used.

A first (or "fill") spot on the face of the cathode-ray tube is bombarded with a 1-microsecond pulse of beam current. The beam then is deflected off a small distance to a second (or "spill") spot and turned on for 4 microseconds N times. After this the beam is returned to the original spot and the process repeated. Signals produced when the fill spot is bombarded are observed in the usual manner[1] by means of a pickup plate on the face of the tube and a suitable amplifier. If N is small enough and the spacing between the two spots is large, the normal negative or "dot" signal is obtained from the fill spot. As the 4-microsecond spill spot is brought in closer and closer, the signal from the 1-microsecond fill spot decreases in amplitude, goes positive, and reaches a maximum value when the spill spot stands at the optimum distance for filling. With further decrease in the separation between spots, the signal decreases in amplitude, goes negative, and finally reaches its original negative amplitude when the two spots are superimposed. In making measurements, N is set for a particular value and the separation of the spots is decreased until the negative signal from the fill spot decreases to one-half of its original negative amplitude (this represents an arbitrary

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* The *IBM-79* tube has been registered with the Radio-Television Manufacturers Association and assigned the type number *3VP1*.

† Bit is defined as a unit of information capacity, equal to one binary decision, or the designation of one of two possible values or states of anything used to store or convey information.

Essentially full text of a conference paper recommended by the AIEE Committee on Computing Devices and presented at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952.

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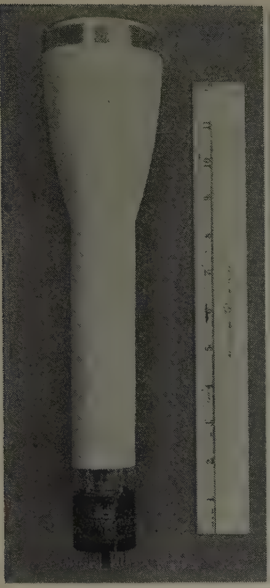
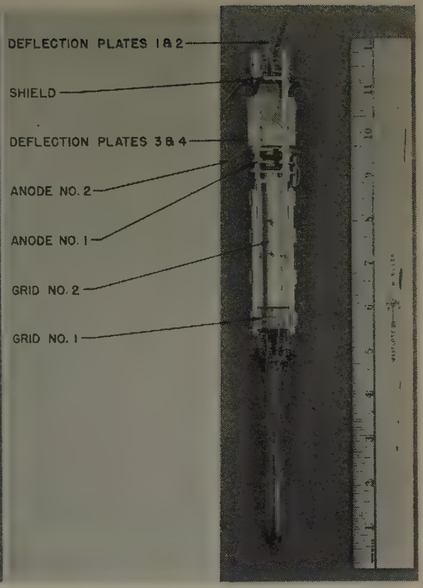
The author is grateful to various persons in the laboratory who have contributed to the development of the *IBM-79* tube. In particular, appreciation is expressed to J. B. Little who supervised the construction of a large number of experimental tubes; to C. Karan who worked out techniques for the elimination of screen blemishes; to R. DeLano who devised test circuits; and to D. R. Young who contributed much helpful discussion.





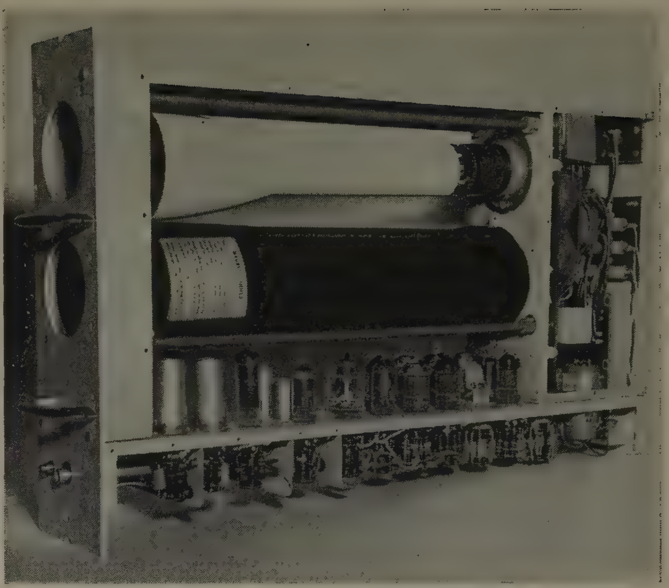
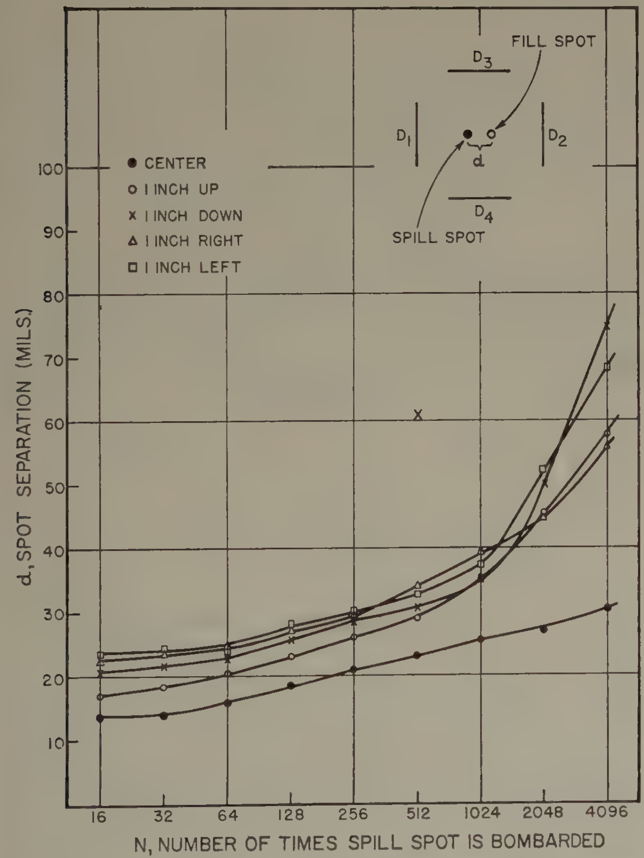


Figure 1 (left). IBM-79 Williams storage tube, whose external conductive coating serves to reduce pickup of spurious pulses at the signal plate. **Figure 2 (middle).** The elements of the IBM-79 with the envelope removed. Grid number 2, anode number 2, and the shield are connected electrically. **Figure 3 (right).** The magnetic shield for one tube and the side panels have been removed from this 2-tube experimental memory unit



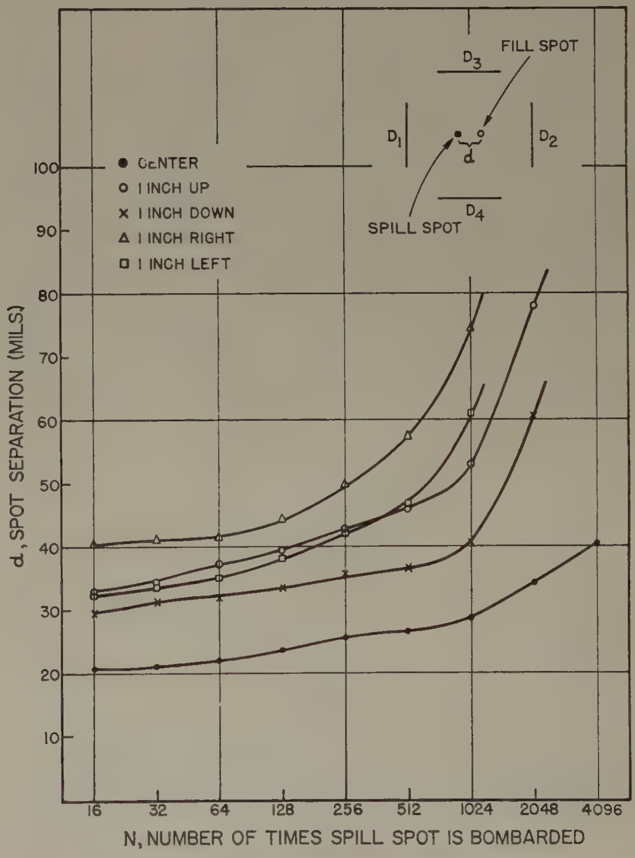


Figure 4 (left). Data taken for these spill curves for an IBM-79 tube were taken at 2,500 volts between the cathode and anode number 2 with no astigmatism voltages; the beam is focused at electrical center of tube. **Figure 5 (right).** Spill curves for type 3KP1 tube

amount of spilling). At this point the center-to-center separation of the spots is measured with a cathetometer.

Figure 4 shows a plot of the separation between the two spots as a function of *N*, the number of times the spill spot is bombarded. These spill curves were taken on an *IBM-79* tube. The lowest curve represents data taken at the center of the screen whereas the upper curves give corresponding data with the two spots deflected out from the center in the directions of the four plates. In Figure 4, the lowness of the top curve and the small spread between curves are indications of the utility of the tube for storage purposes. To operate without danger of loss of stored

Table I. Spot Size and Magnification Ratio

(All at 2,500 Volts and Approximately Equal Current Densities)

	5UP1	3KP1	IBM-79	IBM-77	Exp.-2700
Object distance, inches	1.91	1.91	3.04	3.72	5.53
Image distance, inches	10.21	7.06	8.09	7.41	7.06
Magnification ratio	5.35	3.69	2.66	2.00	1.28
Spot diameter, mils	19.0	14.5	11.5	9.5	6.75

information by the spilling of charge from one spot to another, such combinations of spot spacings and *N* as fall above the curves must be used. For comparative purposes, Figure 5 shows a similar set of curves for a standard *3KP1* tube which is one of the best commercially available 3-inch tubes for Williams storage. The superior performance of the *79* arises primarily from its smaller spot size and reduced deflection defocusing.

Spot Size and Deflection Defocusing. The basic requirement for a higher density of stored information (or more references per regeneration at a given information density) is a smaller spot size. The focused spot on the screen is an image of a point of minimum beam diameter (the crossover) located just in front of the cathode. The most effective way of reducing spot size is to decrease the magnification of the gun. This may be done either by increasing the crossover-to-lens distance or by reducing the lens-to-image distance. The latter approach is not desirable since it means that large deflection angles, with consequent increased deflection defocusing, must be used. Table I lists the magnification ratios and undeflected spot diameters for three experimental tubes and two commercial tubes which are commonly used for storage applications. While it is possible to reduce spot size considerably by making the gun longer, other disadvantages of small spots, such as reduced signal output, greater sensitivity to screen blemishes, and less total available beam current, must be considered and a compromise made at some point. The optimum spot size is determined to a large extent by the degree of deflection defocusing present, for it is obviously pointless to have a very small spot at the center which defocuses badly on deflection. In designing the *IBM-79* a magnification ratio of 2.66 was chosen to be consistent with the minimum deflection defocusing that could be achieved.

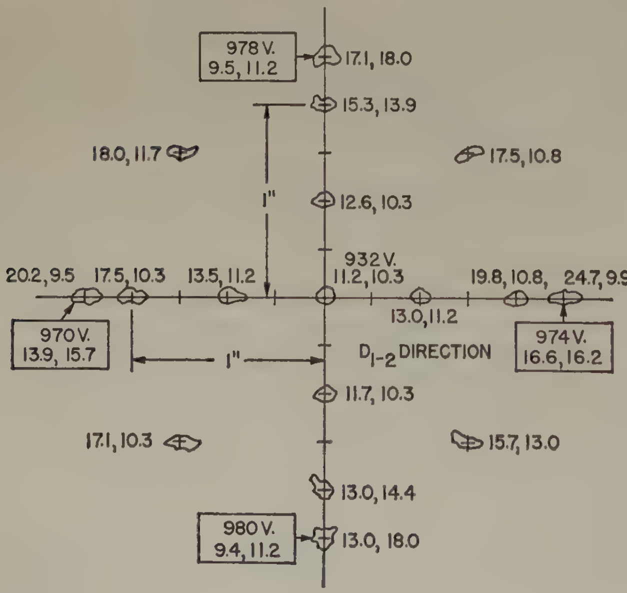


Figure 6. A typical deflection defocusing pattern for an IBM-79 tube. The numbers associated with each spot give the maximum horizontal and vertical spot dimensions in mils

To a first order, the degree of deflection defocusing is determined by the diameter of the beam as it passes through the deflection space. Since the beam current required for storage purposes is not as great as that required for the usual applications, it has been possible to mask the beam down to 0.040 inch at the first-anode aperture. Also, the deflection plates are long ($1^1/_4$ inches) and of a shape calculated to minimize defocusing. As a result of the reduction in beam diameter the deflection plates could be moved closer together to increase deflection sensitivity. In the *79* the minimum plate spacing is 0.075 inch. The alignment of the gun and deflection system must be held to very close tolerances to insure that the beam does not strike the plates when the useful area of the screen is scanned. Low-energy secondary electrons from the plates can deteriorate the spill characteristics of a tube by filling potential holes on the target and converting dot signals to dash signals. For the same reason, the aperture in the second anode was made 0.050 inch to insure that all beam masking would take place at the 0.040-inch first-anode aperture. Low-energy secondary electrons generated at the edges of the first-anode aperture are not likely to reach the target because of the strong retarding field in the first part of the lens.

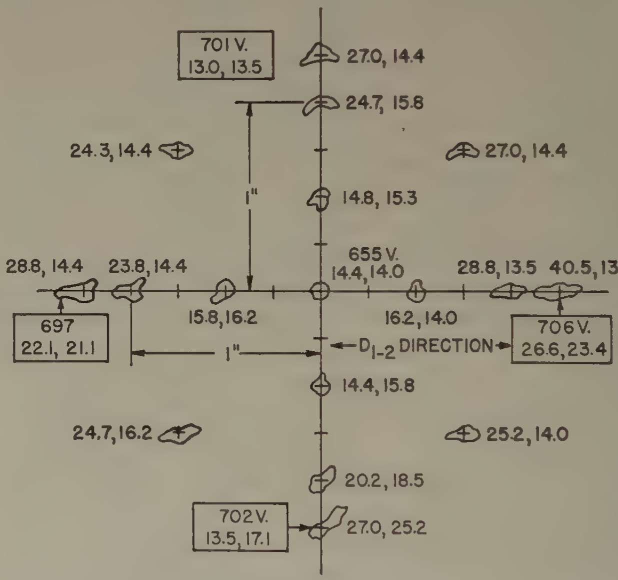
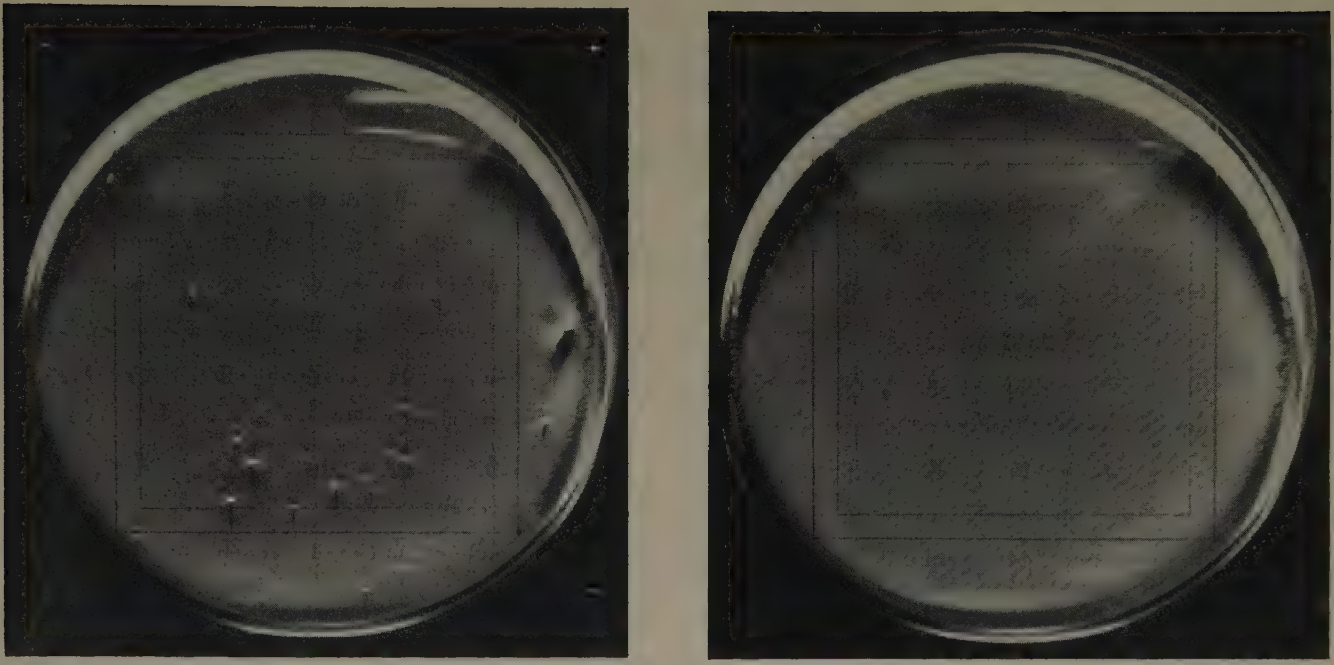


Figure 7. The deflection defocusing pattern for a 3KP1 tube

Figure 6 shows the kind of spot distortions obtained at various parts of the target for a typical *IBM-79* tube. The spots are greatly enlarged but drawn to scale relative to each other. The first figure gives the maximum horizontal dimension and the second gives the maximum vertical dimension in mils. The spot is focused at the



Figures 8(A) and (B). The target blemishes shown on the screen of a particularly bad tube are shown in (A) before sparking to remove the spots and their removal after sparking is shown in (B)

electrical center of the screen and no astigmatism voltages are used. The boxed figures at the extreme positions give the spot size which may be achieved by refocusing to the indicated voltages at these positions. In storage operation, of course, a compromise focus voltage is used to give the best over-all spot size. Little, if any, improvement in the whole deflection defocusing pattern could be achieved through the use of fixed astigmatism voltages between either or both sets of deflection plates and the second anode. For comparative purposes, Figure 7 shows a typical deflection defocusing pattern obtained on a *3KP1* tube.

Screen Blemishes. The elimination of screen blemishes or "bad spots" has been one of the most serious problems in the development of a more satisfactory tube for Williams storage. A large amount of work has been done on this problem, and while it is not completely solved at this time sufficient progress has been made to make the manufacture of tubes entirely free of bad spots economically feasible. In the production of 183 experimental *IBM-79* tubes, there were 60 per cent with no bad spots, 25 per cent with 1 bad spot, 9 per cent with 2 spots, and 7 per cent with 3 or more spots. This record includes a good deal of experimentation on processing techniques, and it is felt that a considerably higher yield of perfect screen tubes could be obtained in commercial manufacture.

Two main factors are involved in the production of spot-free tubes: the first is the scrupulous control of dust and dirt in the assembly area, and the second is the development of a simple technique for the removal of such few bad spots as may be present in the finished tube. Screening, dag-coating, mounting, and sealing-in operations are carried out in an area supplied with conditioned precipitron-filtered air. About 90 per cent of the bad spots found in finished tubes can be removed by sparking the screen externally with an ordinary Tesla coil of the type used for vacuum leak detection. The intense electrostatic forces created by this treatment cause foreign particles to fly off the screen by mutual repulsion. Once removed, the particles do not return to the screen in normal handling of the tube. However, if the tube is held face down and struck a few sharp blows, new bad spots can be created. Such spots may be removed with virtually 100-per-cent efficiency by sparking. Figure 8*A* shows a map-type presentation of the bad spot signals on a particularly bad *IBM-79* tube; Figure 8*B* shows the tube after sparking.

Deflection Sensitivity, Signal Output, Shielding. Because of the relatively small diameter of the electron beam in the deflection space, it has been possible to achieve a high deflection sensitivity on the *IBM-79.* At 2,500 volts accelerating potential, the sensitivity of the deflection plates 1 and 2 (nearest the screen) is 95 volts per inch, and that of the deflection plates 3 and 4 is 78 volts per inch. The high deflection sensitivity proves valuable in reducing access time or in reducing amplifier power required for a given positioning time. To control the tube-to-tube variation in pattern size when a large number of tubes are used in a store, the deflection sensitivity range is held to ±10 per cent. The capacity of the deflection plates with respect to other gun electrodes, particularly the control grid, has been balanced to reduce any tendency of the beam to twitch as the grid is unblanked. Some of the more important interelectrode capacitances of the *IBM-79* are listed in Table II.

To reduce the pickup of spurious signals at the signal plate, particularly from grid unblank pulses and deflection transients, the outside of the bulb is coated with a conductive silver paint having a resistance of less than 4 ohms from one end to the other. A number of spring metal fingers located near the output end of the tube make

Table II. Interelectrode Capacitances of IBM-79

Electrodes	Capacitance, Micromicrofarads	Electrodes	Capacitance, Micromicrofarads
K to all	4.7	*D3* to all	7.0
G1 to all	7.0	*D4* to all	7.0
D1 to *D2*	3.0	*G1* to *D1*	0.3
D3 to *D4*	2.6	*G1* to *D2*	0.15
D1 to all	7.0	*G1* to *D3*	0.17
D2 to all	8.3	*G1* to *D4*	0.12

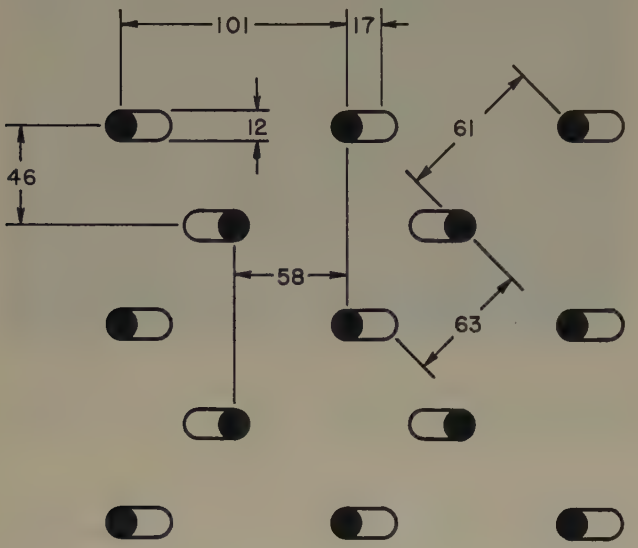


Figure 9. The dimensions are in mils in this hexagonally packed dot-dash array with alternate dash directions in successive rows

contact with this coating. The internal collector impedance also is made as low as possible to improve the signal-to-noise ratio.

Because of the reduced spot size, the output signal from the *IBM-79* is about 50 per cent lower than that obtained from most commercial 3-inch tubes; however, it is adequate for reliable operation. The *IBM-79* uses a willemite phosphor operated at 2,500 volts. There is some evidence that the signal output at this voltage may be doubled through the use of a calcium-tungstate phosphor.

APPLICATION

The utility of simple 2-spot spill curves in predicting tube performance may be illustrated by a typical application of the *IBM-79* tube. Suppose it is desired to store 1,024 binary bits of information under conditions where 512 readouts may be made on any given spot without loss of information in adjacent spots. Figure 9 shows one kind of spot array that may be used for this job. It is a hexagonally packed dot-dash layout wherein the dash directions alternate in successive rows. Since the interaction between spots involves the spill of negative charge into the potential wells of dots rather than into those of dashes, the use of alternate dash directions permits a denser packing of information than would be possible otherwise. The shortest distance between a dot and any other bombarded region of the target is 61 mils. It can be seen that this operating point (marked *X* in Figure 4) lies well above the spill curves for the *IBM-79*.

There is a considerable safety factor in the fact that the operating point lies 31 mils above the highest curve. In addition, there are several other considerations which function as further safety factors in this simple analysis: 1. The over-all pattern size for the array shown in Figure 9 is 1.50 by 1.63 inches; thus, the edge spill curves are taken further from the center than any of the spots in the array are actually located. 2. The curves of Figure 4 were taken with the spot focused at the center. The average level of the curves may be lowered by focusing nearer the edge. 3. The nearest part of adjacent spots is not bombarded a full 4 microseconds as is the case for the spill data. 4. There is some experimental evidence that when many other spots are present around a particular spot being bombarded they serve to funnel away some of the "gentle rain" (that is, low-energy electrons which do not originate at the screen) that would contribute to the filling of the fill spot in a 2-spot experiment.

The problem of gentle rain has not yet been completely solved in the design of an improved Williams storage tube. Because of the effect mentioned previously, there is some doubt as to its actual importance in a tube operating with a full array. It is believed, however, that gentle rain is responsible for the sharp rise in some of the spill curves at large values of *N*. Probe experiments, and experiments wherein the main focused beam is trapped in a Faraday cage while stray currents reaching the target are measured, show that diffuse gentle rain currents several thousand times less than the beam current are present in most cathode-ray tubes. This is about the right order of magnitude to account for the sharp rise in spill curves.

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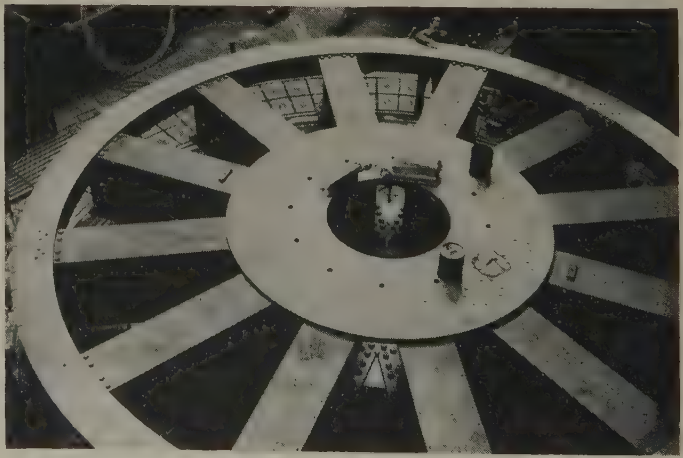
Wheel of Power



This rotor spider for a 27,000-kva 69.2-rpm hydrogenerator is being built by the General Electric Company, Schenectady, N. Y. Twenty-nine feet in diameter, the rotor is shown mounted on a boring mill where the plate brake, on the outside periphery of the spider, has just been machined

Application of Hydrostatic Lubrication in Vertical Water Wheel Thrust Bearings

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Two systems are described for applying hydrostatic lubrication to pivoted-pad thrust bearings during starting of vertical water wheel generators. These are the externally pressurized system and the hydraulic lifting system. Current design features and practices of both systems are discussed.

THE PIVOTED-PAD thrust bearing as now used on many large water wheel generators maintains a thick oil film automatically at normal speed as a result of hydrodynamic action. During the starting period, however, there is no oil film and the bearing surfaces are in metal-to-metal contact. When accurate, smooth rubbing surfaces and suitable lubricants are used, long operating life can be obtained without appreciable bearing wear.[1] Many bearings, after 25 years or more of operation, are still in very good condition.

The first pivoted-pad bearing was installed by Professor Kingsbury in 1912.[2] This bearing was subjected to the usual frequency of starts and stops and in 1937 the bearing surfaces were inspected. The wear on the babbitt pads was very small. The bearing was reassembled without further maintenance and has been operating successfully since that time.

At the Calderwood (Tennessee) Power Station of Knoxville Power Company (wholly owned subsidiary of Aluminum Company of America), a similar condition was found on a 64-inch thrust bearing installed in 1930 and inspected in 1950. These experiences have been repeated on many other similar machines, indicating that the pivoted-pad bearing has been a very reliable piece of equipment which can withstand many years of operation without ill effects.

However, on water wheel generators used for peak load operation, the frequency of starting and stopping is high. Furthermore, if frequent starts must be made with high lubricating oil temperatures, the starting conditions are more severe than usual. When these starts are accompanied by chatter in the bearing, the operating personnel feel that more positive lubrication is desirable during the starting period. Some operators therefore have installed auxiliary means of providing an oil film previous to starting.

Two methods have been used successfully for providing a hydrostatic oil film between the bearing surfaces.

The externally pressurized system utilizes high-pressure oil to carry the applied load on a bearing pad, thus forming a thick fluid film.[3] In this case, a high-pressure area in the center of each pad must be provided to distribute adequately the oil flow and resultant hydrostatic pressure symmetrically over the bearing surface. This alteration of the bearing surface must not interfere with the proper hydrodynamic operation of the bearing pad.

The second method of obtaining a hydrostatic oil film during the starting period is to use the principle of an oil cushion. In this case, an oil film is introduced between the bearing surfaces by physically separating them and allowing oil to fill the space. The viscosity of the oil will resist extrusion and thus a load-carrying oil film can be maintained for an appreciable length of time. During this period, the starting friction is practically eliminated and low-friction starting can be obtained. This system can be applied conveniently to vertical water wheel generators, where the combined hydraulic brakes and jacks are used to raise the rotor and separate the bearing surfaces.

The principles of hydrostatic lubrication have been used extensively ever since the first exhibit of the load-carrying ability of an externally pressurized oil film at the Paris Industrial Exposition of 1878.[3]

It is used universally now to provide an oil film prior to starting on some machines when the available starting torque is not sufficient, such as synchronous condensers or motor generator sets. An early application to pivoted-pad thrust bearings was in 1929 on a vertical synchronous condenser for the Toronto–Leaside-Transformer Station of the Hydro Electric Power Commission of Ontario.[4]

Before 1910 some vertical hydroelectric or steam-turbine generators were supported by means of externally pressurized step type thrust bearings.[5] This bearing required a continuous supply of high-pressure oil and failure of the high-pressure oil system usually resulted in bearing failure.

After the development and successful application of the Kingsbury–Michell pivoted-pad thrust bearing, the oil film in these bearings was formed automatically by hydrodynamic action. Auxiliary pressure pumps were no longer required. During the starting period there is metal-to-metal contact in all bearings but in all applications of journal and thrust bearings where sufficient power is available to overcome the high static starting friction and break away the bearing, it is normal practice to start the units from rest without resorting to auxiliary means for providing an oil film.[6] This successful experience has been confirmed by means of many laboratory and field experiments. The

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Full text of paper 52-44, "Application of Hydrostatic Lubrication to Vertical Water Wheel Generator Thrust Bearings," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. Scheduled for publication in AIEE *Transactions*, volume 71, 1952.

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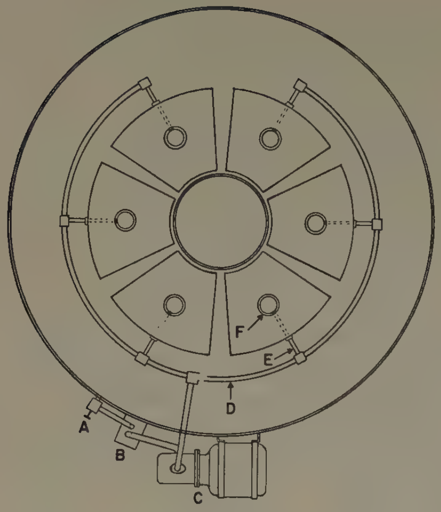


Figure 1. Typical hydrostatic lubrication piping diagram

recent addition of hydrostatic lubrication to vertical water wheel generator thrust bearings has been prompted by the desire to provide the maximum factor of safety during the starting periods and where critical power requirements warrant extra precautions, as well as to prevent undue wear during the stopping period.

AN EXTERNALLY PRESSURIZED HYDROSTATIC SYSTEM

In 1950, inspection of a 20-year-old bearing on a 45,000-kva vertical water wheel generator at the Calderwood Power Station showed that the bearing surfaces were well run in and highly polished, and that some babbitt had been tinned to the runner in spots, indicating the bearing pads were susceptible to trouble in the future. The bearing involved is a 64-inch diameter pivoted-pad thrust bearing with six pads carrying a maximum thrust load of approximately 703,000 pounds. Since its installation in 1930 and until 1945, this generator on the Knoxville Power Company's system had operated on a fair load factor industrial load. Since 1945, the unit has been used largely for peaking capacities and has been subject to an increased frequency of starts and stops.

Preventive maintenance measures were considered. Critical power conditions coupled with a high frequency of starts and stops led to the conclusion that positive lubrication during the starting period was desirable. The application of hydrostatic lubrication was studied and the externally pressurized system was selected for this application. The cost of this auxiliary lubricating system was found to be reasonable when considering what would be the loss of generator peaking capacity resulting from a bearing failure.

In this case, the maintenance and operating personnel felt that a smooth, effortless start was of prime importance. Several times in the past it had been temporarily impossible to stop completely a generator because of debris interference at the wicket gates. The turbine would continue to rotate at a very slow speed and it was feared that there was intermittent metal-to-metal contact and wear in the bearing. The auxiliary hydrostatic lubricating system would therefore be useful for providing an oil film during such conditions.

Theory. The application of externally pressurized hydrostatic lubrication to any of the standard hydrodynamic bearings requires that the high-pressure oil be introduced approximately in the geometric center of the bearing in sufficient quantity and pressure to provide a thick load-carrying oil film between the bearing surfaces. At this central point, the bearing surface must be relieved sufficiently to provide a well-balanced and distributed oil pressure and flow over the remaining portion of the bearing. However, when altering the bearing surface, care must be taken not to interfere with the hydrodynamic formation of an oil film.

In the multiple-pad thrust bearing on the generator at Calderwood described, provision was made on the bearing surface of each pad for a pressure area. This area was located in the geometric center of the bearing surface, and consisted of a grooved annular ring having a mean diameter of 4 inches and an area of 3.14 square inches. See Figure 1. The use of an annular groove rather than a small high-pressure port insures that the load center will lie within the high-pressure lifting area. This will provide the maximum balance and distribution of oil pressure over the bearing.

The magnitude of the oil film during full speed operation was calculated to be 0.0042 inch. Sufficient hydrostatic oil flow was provided to obtain a film thickness of 0.003 inch during the starting period. The flow requirements were calculated to be 2.17 gallons per minute operating at 820 pounds per square inch. The pressure surge during the initial lift of the rotor is less than double normal operating pressure. For this reason, the system was designed for a pressure of 2,000 pounds per square inch. This is, of course, a conservative design. Actual measurements of the rotor lift checks the design calculations in that the rotor lift has been measured by a dial indicator to be 0.003 inch.

Design Details. In theory, the application of externally pressurized lubrication to a multiple-pad thrust bearing is equivalent in some ways to the conventional system used on sleeve bearings of synchronous condensers and motors.[3] However, the practical application is different; where each sleeve bearing is provided with a closely mounted separate

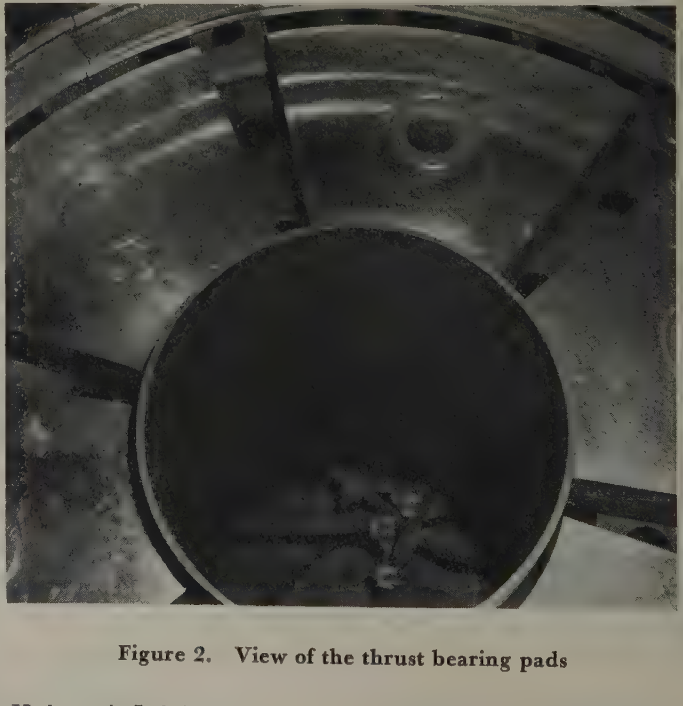


Figure 2. View of the thrust bearing pads

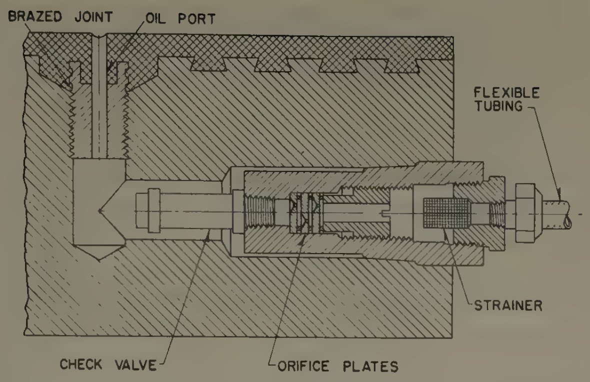


Figure 3. Cross section of bearing pad through oil port with flow regulator and check valve

pumping system, the pivoted-pad thrust bearing has 6 to 12 pads, all of which, for practical purposes, are supplied from one pump. The use of a single pump means that an oil distribution system must be designed to provide adequate flow and pressure at each bearing pad regardless of the load distribution.

The pump and distribution system provided for the Calderwood generator is shown schematically in Figure 1. The entire system, except the oil pump, is mounted inside the oil reservoir. With this arrangement, a minimum of piping is required. However, the system inside the reservoir is not readily available for regular maintenance inspection and repairs. Therefore, the design was based upon obtaining a maintenance-free system.

As shown in the schematic diagram, Figure 1, the equipment necessary to provide hydrostatic lubrication is rather simple in design. A 2,000-pound pressure vane-type constant delivery pump and 3-horsepower motor, built as an integral unit, provide the oil pressure source. The pump and motor are mounted on the thrust bearing oil reservoir. The oil for the pump is supplied from the reservoir at point A, Figure 1. An oil filter with a paper-type cartridge about double the size of a standard automotive-type filter is used in the suction line at point B. The pump, point C, delivers high-pressure oil to the oil header inside the oil reservoir, point D. Flexible high-pressure hose, point E, is used to connect each bearing pad to the oil header. The oil is admitted to the pad and thence through an orifice-type flow regulator and check valve, these being located in a drilled hole in the steel body of tie pad. An annular grooved ring, point F, is in the bearing surface of pad to admit oil for lifting the rotor initially or providing an adequate film of oil at low rotating speeds. Figure 2 illustrates the bearing pads mounted in the bearing tub and showing the oil ports.

Special attention was given to the design of the high-pressure oil port in the bearing surface, so that high-pressure oil would be prevented from entering between the pad and the babbitt, thus loosening the babbitt bond. A special bushing was threaded into the bearing shoe and used as the oil port, as shown in Figure 3. This bushing was provided with anchor grooves for the babbitt. Conventional dovetail grooves were provided in the face of the steel pad. After babbitting the thoroughly prepared and tinned steel surface of the pad, standard shop inspections were conducted. These consisted of inspecting for the possibility of small cracks in the babbitt surface and the quality of bond between the babbitt and the steel pad.

During hydrodynamic operation of the bearing, a load-carrying oil film is formed which has a peak pressure close to the center of the bearing pad. Therefore the auxiliary lubricating system must be provided with a check valve to prevent loss of oil and perhaps complete breakdown of the fluid film. This check valve was installed directly in each pad as shown in Figure 3 without intermediate piping between the valve and the oil port. If a break in the oil line should occur, the hydrodynamic operation of the bearing would not be affected.

To provide a high-pressure fluid film to each thrust pad and prevent loss of the entire flow through one partially loaded pad which might lift before the other pads, a simple orifice-type flow regulator was installed within each pad. This flow regulator is made up of three orifice plates, as shown in Figure 3. The pressure drop through this regulator is dependent upon the fluid flow and is constructed with a large enough pressure drop at normal oil flow to be able to compensate, by a small change in flow, for the unequal lifting pressure requirements of the thrust pads.

Practical Aspects. Simplicity is an all-important feature from the standpoint of operating personnel. In this particular case all unit starting functions are controlled by a single push button on the governor control panel. This includes such functions as starting the turbine bearing oil pump and operating the governor relay which opens the oil valve to the governor control. The starting control for the high-pressure pump also was connected to this same start button and interconnected with a contact on the governor relay. Thus, the pump will start simultaneously with the other unit starting functions and will stop automatically when the unit voltage builds up as the unit comes up to speed. Figure 4 is a schematic of the control circuit.

A fail-safe feature is most desirable in the application of the hydrostatic lift. Failure of control equipment to function properly during the starting period will result in a start without the aid of prestart lubrication or continuous operation of the pump. In either event equipment will not be endangered. The pump and motor unit were mounted externally on the bearing reservoir to eliminate the necessity of electrically insulating the oil lines, as shown in Figure 5. Furthermore, the pump unit is easily accessible for maintenance and visual inspections.

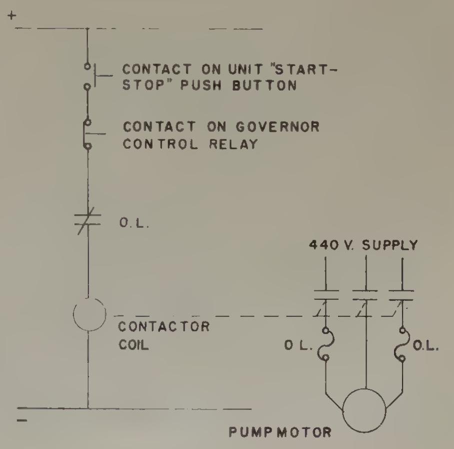

+
CONTACT ON UNIT "START-STOP" PUSH BUTTON
CONTACT ON GOVERNOR CONTROL RELAY
O.L.
440 V. SUPPLY
CONTACTOR COIL
O.L.
O.L.
−
PUMP MOTOR

Figure 4. Control schematic for hydrostatic lubrication system

Figure 5. The hydrostatic pump and motor mounted on bearing reservoir

However, the entire distribution system is located inside the oil pot and is inaccessible for preventative maintenance. If an oil line should break, the complete hydrostatic lubrication system would be inoperative until repairs could be made; but, since these bearings can be operated without starting lubrication, this type of failure would not interfere with the availability of the generator.

Considerable care must be taken during the initial installation of this type of auxiliary lubricating system to prevent the introduction of foreign particles, such as dirt or grit, between the bearing surfaces. The oil reservoir and the auxiliary piping system must be cleaned thoroughly and kept clean to prevent damage to the babbitted surfaces and runner surface and to prevent plugging the filters and flow regulators, thus causing the system to fail.

Using established practices in designing externally pressurized hydrostatic lubricating systems and recognizing the special requirements involved in applying it to a pivoted-pad thrust bearing have resulted in a very successful application as described herein.

AN AUTOMATIC HYDRAULIC ROTOR LIFTING SYSTEM

Providing an oil cushion between the thrust pad and runner of large thrust bearings for vertical water wheel generators, by means of an automatic rotor lifting system, has been used effectively to obtain easy low-friction starting lubrication.

This system utilizes the combined hydraulic brakes and jacks of the machine to lift the rotor prior to starting, thereby introducing an oil film between the bearing surfaces. The lifting cycle is operated from the governor panel. The usual method of starting is carried out in the following sequence: the rotor is raised, introducing oil between the bearing surfaces; then, with the rotor held in the raised position, the preliminary electrical switching and other preparations for starting are made; then the lowering cycle is carried out just prior to the required starting time by an automatic control system, which permits the rapid controlled drop of the rotor in 1 to 1.5 minutes. A typical record of the lowering time required for a large rotor is shown in Figure 6.

Thus the thrust bearing surfaces are separated by an oil cushion which will take an appreciable time to squeeze out. Calculations based on the hydrostatic oil cushion theory show that an appreciable oil film will still be available 5 to 10 minutes after lowering the rotor. Refer to Figure 6. Even after this period of time, large pools of oil a few tenths of a mil thick will be available for providing low-friction starting. An excellent demonstration of the frictionless starting of a large bearing carrying 1,000 tons was obtained when several men were able to turn the rotor by hand approximately 5 to 10 minutes after lowering the rotor.

Theory of Operation. The use of the braking system of a vertical water wheel generator for providing starting lubrication can be accomplished by the addition of a few parts to the conventional pneumatic braking system. A high-pressure pump is provided to develop the required oil pressure for the lifting operation. During the lowering cycle, the weight of the rotor is used to force the oil out of the brakes, through a flow control and back to a reservoir. The only remaining equipment required is for the automatic control system and consists of limit switches, solenoid valves, and indicating meters.

The controls, of course, are provided to assure the proper sequence of operation and to prevent faulty operation. Special controls can be provided to anticipate and correct almost any fault in the operation of the system.

The automatic hydraulic lifting system must be able to perform three functions efficiently and automatically.

1. In the braking operation, the brakes are used to stop the rotating parts of the generator and turbine. Usual requirements are that the rotor be stopped in 10 minutes from one-half normal speed. They also are used to prevent rotation of the shaft when leakage occurs through the turbine gates. With the automatic hydraulic system, oil is

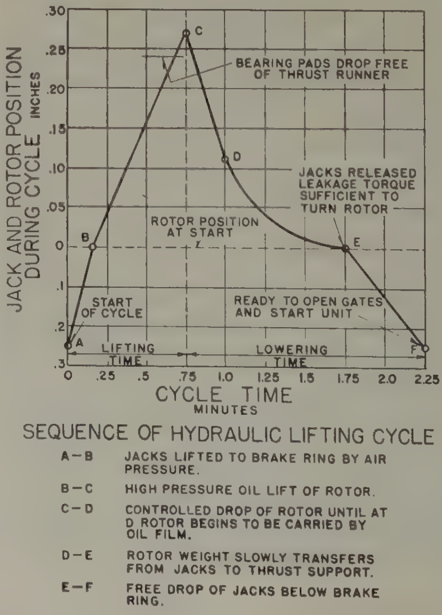


Figure 6. Sequence of hydraulic lifting cycle

maintained in the brake system by means of check valves and during braking 100 pounds per square inch air pressure is applied to the oil tank and thus to the brakes.

2. In the jacking operation, the brakes are used as hydraulic jacks to lift the generator rotor off the thrust support as required for regular maintenance inspections or during adjustments of the bearing pad jackscrews. With the high-pressure pump supplied, rapid jacking is accomplished.

3. In the lifting operation, the brakes are used to provide an oil film between the bearing surfaces.

A schematic outline of the automatic hydraulic lifting system is shown in Figure 7. During the automatic lifting operation the following sequence is carried out.

1. Operation of the lifting switch starts the high-pressure pump. When the rotor has been raised 1/4 inch, a limit switch on the shaft shuts off the pump and lights an amber light indicating the end of the lift cycle.

2. Returning the switch to lower open valves 4, permitting oil to return to the tank through flow control 9. When pressure in the system drops to 200 pounds per square inch, spring-actuated valve 5 opens, permitting rapid return of the oil to the tank. When brakes are in the down position, the brake limit switches will close valve 5 to keep the system filled with oil. Green signal lights will signify the machine is ready to start.

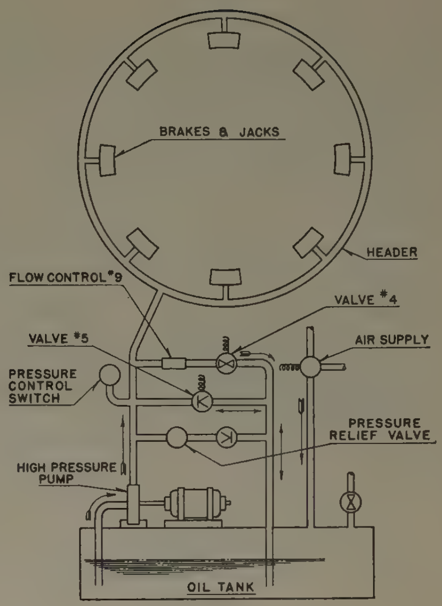
Design Details. Normally a pressure of 1,500 to 2,000 pounds per square inch is required in the hydraulic jacks to support and lift the entire weight of a water wheel generator rotor. A 2,000-pound-per-square-inch vane-type constant-delivery pump provides this source of pressure.

During the lifting operation, check valves are provided which positively prevent loss of pressure in the system; in addition a pressure indicator and rotor position indicator are supplied, so that the operator can be informed of the progress of the cycle.

During the lowering cycle, a flow regulator is used to restrict the rate of descent of the rotor and provides controlled safety during this operation.

Two solenoid valves are used to control the oil flow during the cycle. Referring to Figure 7, these valves are the high-pressure valve number 4 and the low-pressure valve number 5. The high-pressure valve was designed particularly for this application. Normally it is closed and acts as a positive seal against oil leakage. The solenoid is used to open the valve against full lifting oil-line pressure of 2,000 pounds per square inch. Opening this valve starts the lowering cycle. The low-pressure valve is designed to act as a check valve under two conditions: first, when the solenoid is energized; and second, at all times when the lifting pressure is greater than 250 pounds per square inch. The low-pressure control is usually set for 200 pounds per square inch and at that pressure de-energizes the low-pressure solenoid number 5, which permits the rapid draining of oil and dropping of the jack pistons. When all jack pistons have dropped to a preset position below the brake ring as indicated by limit switches, the operator at the control panel is signaled by green lights that the unit is ready to start. At the same time, the oil is sealed in the system and the unit is in a ready position, available for preforming any of the three required functions of the automatic hydraulic lifting system.

Figure 7. Schematic outline of hydraulic lifting system



Practical Aspects. The hydraulic lifting system performs the function of providing an oil film between bearing surfaces without any additions to the existing construction of the pivoted-pad thrust bearing. The system therefore eliminates any risk to the normal hydrodynamic bearing life that can be possible with the introduction of high-pressure oil holes and grooving in the babbitt bearing surface. Risk of introducing foreign material between the bearing surfaces by means of an auxiliary oil supply is also eliminated.

Since the pump, valves, and controls are mounted outside the machine, regular inspections and maintenance of the system can be carried out readily during brief shutdown periods or even during normal operation.

It has been shown that when an oil cushion is established between bearing surfaces, as is accomplished with the hydraulic lifting system, an appreciable length of time is required to squeeze the oil out. The lifting cycle normally can be performed in 2 to 3 minutes, after which an adequate oil film is maintained for approximately 5 to 10 minutes.

CONCLUSIONS

The application of hydrostatic lubrication to water wheel generator thrust bearings during the starting period has been accomplished by two systems, the externally pressurized system and the hydraulic lifting system.

As described in this article, the two systems have been improved to provide a high degree of reliability and serviceability. Each is quite different in operation, and the choice as to which is selected for a particular application usually is based upon individual preferences. Both have been successfully applied to large thrust bearings.

The hydraulic lifting system has been provided on vertical water wheel generators for many years and in some instances has been used for establishing an oil film during the initial starting period after installation. The improved automatic system has made it possible to use the hydraulic lifting prior to all starts, and units using this system have been in operation for 3 years.

The externally pressurized system has been applied to large thrust bearings in the past to provide an oil film during the starting period. The improved system as applied to the Calderwood generator has been in service for 1 year and its operation has been entirely satisfactory. Several other variations of this installation have been in service for periods up to 10 years.

Hydrostatic lubrication during the starting period of a large thrust bearing has increased the operating factor of safety. This higher factor of safety has been found desirable where frequent starting is necessary and where critical peak power requirements are encountered.

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An Electronic Analogue for an Economic System

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A macrodynamical economic system is simulated with electronic circuits to study the effects of various parameters on stability. Included in the circuit are the delay between the investment of money and the production of goods, the time constant of depreciation, the distribution of manufactured goods, increase of capital goods, and national consumption.

THE SCIENTIFIC METHOD consists of presuming an hypothesis, operating on it with mathematical or other logical techniques, and deriving a conclusion which can be checked against reality. The language of mathematics is best adapted for predicting, as distinguished from prose, which is used more often to describe. As an aid to using the tool of mathematics, one finds techniques of visualization important. For example, the mathematics of oscillating voltages can be described by vector diagrams, which often add clarity, and then these vector diagrams may be converted into circle diagrams, or others which represent the loci of ends of vectors. Another example of a tool for visualization is conformal plotting techniques where poles and zeros of a function are represented by contours on a complex plane. Another technique is the use of equivalent circuits so that magnetic, mechanical, or field problems can be represented as circuit problems. Sometimes several steps are used in this process of visualization as, for example, when waveguide problems are resolved first into equivalent circuits, then into vector diagrams, and, lastly, to mathematical or analytical representations. An analogue is a way of thinking. It is a tool for visualization of a problem. In this particular case an analogue is used to represent an economic problem in terms of circuit notations.

KALECKI'S MACRODYNAMIC SYSTEM

THIS SYSTEM WAS first postulated by M. Kalecki in a paper presented at the meeting of the Econometric Society, Leyden, October 1933.[1]

One of the basic postulates of Kalecki's macrodynamical system was that deliveries of capital goods lagged behind the investment orders to produce them by the production-time-delay θ, in years. This is expressed in equation 1, in which the notation is that given in Appendix I.

$$L(t)=I(t-\theta) \tag{1}$$

The total volume of existing industrial equipment is equal to the running integral of the deliveries of produced goods minus those required to replace depreciated goods. This is expressed by equation 2.

$$K=\int_0^{\tau}(L-U)dt \tag{2}$$

The rate of production of capital goods, or that component of national income due to the production of capital goods, is assumed to be equal to the average of the investment rate over the past θ years, that is, over the time lag of production. This assumes that there is a contribution to

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national income due to the wages earned before a product is available for sale. This is expressed in equation 3.

$$A=\frac{1}{\theta}\int_{t=\tau-\theta}^{\tau} Idt=\frac{1}{\theta}\int_{0}^{\tau} I(t)\,dt-\frac{1}{\theta}\int_{0}^{t=\tau-\theta} I(t)\,dt \qquad (3)$$

This definite integral is instrumented as the sum of two integrals. The second one can be simplified by making the substitution that $t=y-\theta$, and replacing investment rate by the correct function of delivery rate:

$$\frac{1}{\theta}\int_{0}^{y=\tau} I(y-\theta)dy=\frac{1}{\theta}\int_{0}^{y=\tau} L(y)dy=\frac{1}{\theta}\int_{0}^{t=\tau} L(t)dt \qquad (4)$$

When equation 4 is substituted back in equation 3,

$$A=\frac{1}{\theta}\int_{0}^{\tau}(I-L)dt \qquad (5)$$

This says that the rate of production of capital goods is equal to the integral of the difference between the rate of investment orders and the rate of delivery.

The national income is formed of two components, that due to the production of capital goods and that due to the consumption of consumers' goods.

$$B=A+C \qquad (6)$$

The second basic postulate of Mr. Kalecki was that consumption varied as the sum of a constant irreducible minimum plus a component proportional to national income. The introduction of this second component is equivalent to the introduction of positive feedback into society. It is represented by the parameter λ in equation 7.

$$C=C_m+\lambda B \qquad (7)$$

Combining equations 6 and 7 in equation 8 shows that the national income varies inversely as one minus the positive feedback from national income to consumption. If λ should go to unity, then the national income would become infinite.

$$B=(A+C_m)/(1-\lambda) \qquad (8)$$

The investor tries to follow a schedule which will result in maximum profit. The greater the national income, the greater the demand for, and the opportunity to sell, capital goods. Therefore, he would like to increase investment in proportion to national income. This is represented by the coefficient α. Likewise, if there is a great volume of existing industrial equipment on hand, there is less incentive to produce new industrial equipment and therefore he would invest following a schedule which would decrease the investments as the existing volume of industrial equipment increased. These two factors are shown in equation 9.

$$I=\alpha B-nK=\frac{\alpha(A+C_m)}{(1-\lambda)}-nK \qquad (9)$$

The block diagram of the basic equations 1, 2, 5, and 9 is shown in Figure 1. Investment orders enter the time delay function, θ, and emerge a short time later as deliveries, L. These, minus the depreciation, can be integrated to represent the total industrial equipment on hand, K. The difference between investment orders and deliveries is the production in progress and the integral of this is that component of national income due to production of capital goods. The last block, equation 9, includes both the consumers' positive feedback factor λ and the investors' schedule for maximizing profit.

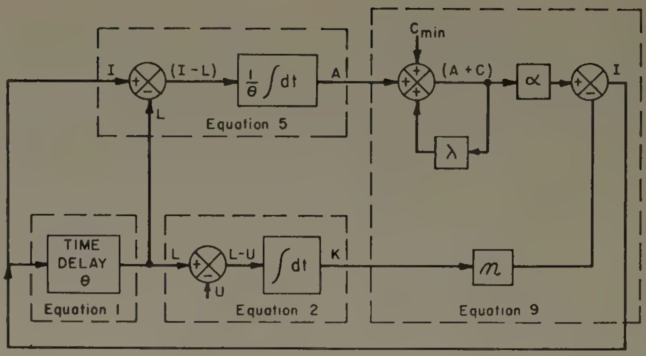

Figure 1. Circuit analogue of Kalecki's economic system

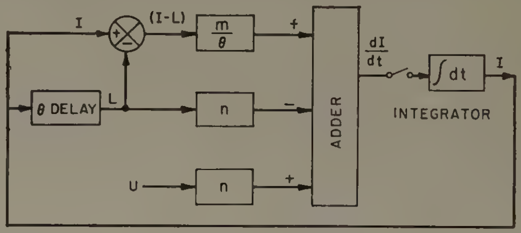

Figure 2. The transformed economic system analogue

This analogue would not be difficult to construct electronically, but it can be simplified somewhat. Since the dynamic characteristics of this system are of greatest interest, this analogue need not be d-c coupled, and constant quantities such as minimum input C can be neglected. Since there are no dynamic factors in the λ feedback loop, it can be represented by the change of scale shown in equations 10 and 11.

$$m=\alpha/(1-\lambda) \qquad (10)$$

$$I=m(C_m+A)-nK \qquad (11)$$

Only one integrator need be used if the adder and coefficients in equation 9 are placed ahead of, instead of after, the integrator. With these block diagram transformations, the system becomes that shown in Figure 2, in which there is only one adder and one integrator and one time-delay element.

ANALOGUE

THIS SYSTEM WAS constructed using the time base of 200 microseconds equal to 1 year. The wiring diagrams are shown in Figures 3 and 4, in which the adder, integrator, and subtractor are standard type components. A perfect time-delay function, however, is not easily realizable. An approximation to it is a 120-microsecond delay line with some compensations for attenuation. A less close approximation is a cascaded 3-time-constant system with the same average time delay. The question immediately arises concerning the shape of the time transient of the delivery of capital goods. The average time delay is 6/10 of a year, but since some goods require only a few months and others several years, it is probably more realistic to assume that the transient waveshape for capital goods is

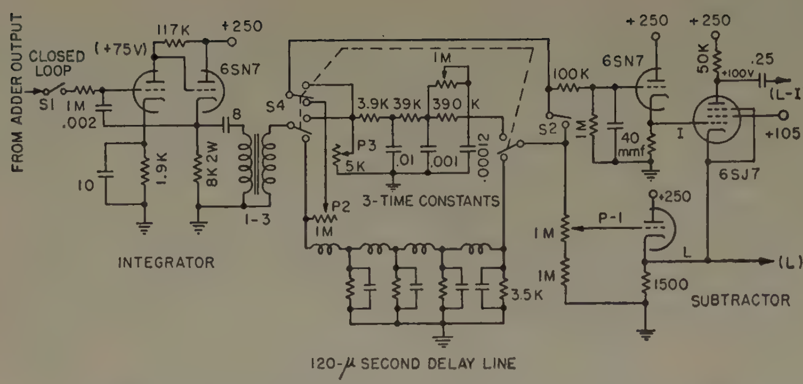

Figure 3. The integrator, delay, and subtractor of the circuit

quite similar to that delivered by a 3-time-constant cascaded system. This analogue has provision for studying the effects of either form of time delay. The adjustment of the system corresponds to setting the loop gains for loops m and n to be equal to that calculated from the equations for the system at some characteristic frequency, for example, 500 cycles per second, which corresponds in a real system to 1 cycle per 10 years. The adjustments are given in Appendix II.

An analogue of this sort can be used in two manners. The open loop transfer function amplitude and phase can be measured and analyzed by conventional servomechanism techniques to determine whether or not it is stable, and the degree of stability and the resonant frequency. The degree of stability then can be correlated with various parameters and ratios of parameters. Another way of using this analogue is to close the loop and introduce a transient, measuring the decrement per cycle or per radian of the oscillation produced by a transient disturbance. In either case, the significant information obtained is the resonant frequency and the dimensionless damping coefficient. The amplitude of the oscillation in any linear dynamic system has no significance. For the amplitude of oscillation to have a meaning, some nonlinear economic function must be postulated, built into the equipment, and then the ratio of an amplitude of oscillation to the amplitude of the transient can be measured in economic terms and compared with the known or expected response. Still, this linear system is very valuable in presenting a visual picture of the influence of various economic factors. More than that, one can see whether the kind of system is capable of being stabilized. It is interesting to note that this system oscillates near 1 cycle per 10 years, the damping coefficient is very low, and the system is quite difficult to stabilize. One way in which this analogue might be used is to design a stabilizing network for it and then reinterpret this network in terms of the economic analogy.

As one trial hypothesis for further studies, a component of depreciation was introduced which was proportional to the rate of change of delivery of goods. That means that when production is decreasing there is a tendency to make old goods last longer, and when production is increasing there is a tendency to want to replace obsolete equipment so that one can use the added efficiency of new equipment. It is interesting to note that the addition of this term, which is shown at the bottom of Figure 4, contributes to the instability of the system and makes it less damped.

Philosophically speaking, there are two factors which contribute to the instability of this system. One is the loss of information due to the time delay θ. This means that investors do not know what other investors have done until their products appear on the market. In reality this might not be so. It may be that there are functions in the economy which do allow investors to predict into the future and know what the change in delivery of capital goods will be. In the absence of this information, though, this dead time contributes to the instability. The second factor is the positive feedback loop of consumption. As long as consumers increase their consumption in proportion with national income (instead of saving) there is an accumulative process which tends to rise to destructive amplitudes of oscillation. The actual economic system is limited by some nonlinear component which is not included here.

This analogue oscillates for certain values of m and n. The measured relationship is shown in Figures 5 and 6. The curve for $\delta=0$ is for sustained oscillations, while those for positive δ are damped oscillatory. It can be seen that increasing either m or n makes the system less stable. Changes in m have a large effect on the degree of stability, while changes in n affect the oscillation frequency most significantly. The substitution of three cascaded time constants for pure dead time increases the stability and reduces the oscillation frequency.

ANALYSIS

SINCE THE ACTUAL economy is known to oscillate, attention can be restricted to the undamped case where $\delta=0$, and m and n can be interpreted as the average parameters over many cycles of a stable oscillation.

Equation 11 is true for the instantaneous values and also for the average values of the variables. Assuming that the average level of the economy is approximately constant,

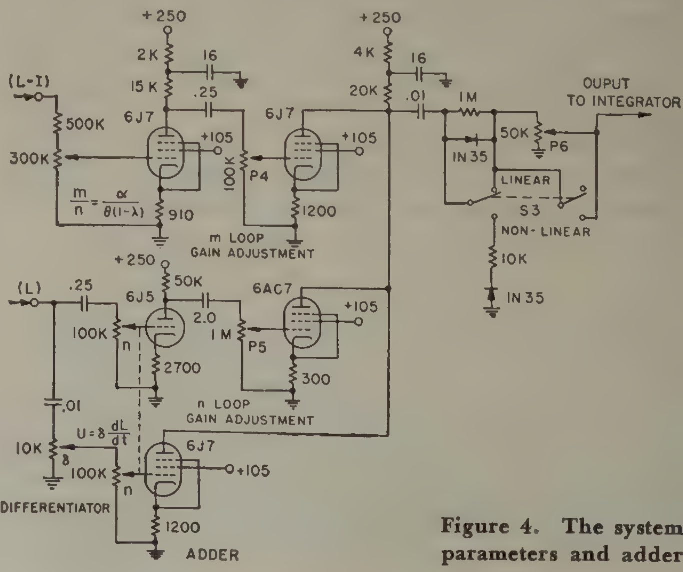

Figure 4. The system parameters and adder

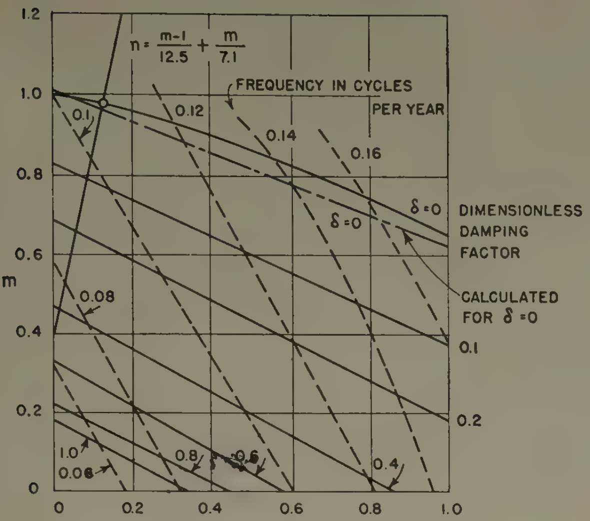

Figure 5. Stability of the economic analogue. θ is a delay line of 0.6 year

the average investment and average production are each equal to the average depreciation U_0. This is expressed by

$$U_0=m(C_m+U_0)-nK_0 \tag{12}$$

Two time constants are defined: the consumption time constant is the length of time it would take to eat up all the capital worth if it were used at the rate given by C minimum. The depreciation time constant is the time it would take to depreciate all of the capital worth.

$$T_c=K_0/C_m\approx 7.1 \text{ years} \tag{13}$$

$$T_u=K_0/U_0\approx 12.5 \text{ years}^1 \tag{14}$$

Substituting these parameters into equation 12

$$n=\frac{m}{T_c}-\frac{(1-m)}{T_u} \tag{15}$$

The consumption time constant is approximately m/n years, but nothing can be said yet about the depreciation time constant, for the system is essentially independent of it.

One must find another relationship between m and n to compare a computed frequency with the observed value. The mathematical solution for the condition of critical stability for this system can be obtained by putting equations 1, 2, 5, and 11 in a-c form:

$$L=I\epsilon^{-j\omega\theta};\qquad K=\frac{L}{j\omega};\qquad A=\frac{I-L}{j\omega};\qquad I=mA-nK \tag{16}$$

The variables can be eliminated between these equations. One minus the open loop gain in vector form becomes

$$1-G=1-\left(\frac{m}{\omega\theta}+\frac{n}{\omega}\right)\sin\omega\theta+j\left[\frac{m}{\omega\theta}-\left(\frac{m}{\omega\theta}+\frac{n}{\omega}\right)\cos\omega\theta\right]=0 \tag{17}$$

Setting the reals and the imaginaries each equal to 0 yields respectively

$$\frac{\sin\omega\theta}{\omega\theta}=\frac{1}{m\left(1+\frac{n\theta}{m}\right)}\quad\text{(condition for unity gain)} \tag{18}$$

$$\cos\omega\theta=\frac{1}{\left(1+\frac{n\theta}{m}\right)}\quad\text{(condition for zero phase shift)} \tag{19}$$

The ratio of equations 18 to 19 yields

$$\omega\theta=m\tan\omega\theta \tag{20}$$

Eliminating the trigonometric functions between equations 18 and 19 gives the relationship between m, n, ω, and θ which is necessary for critical stability.

$$\left(\frac{\omega\theta}{m}\right)^2+1=\left(1+\frac{n\theta}{m}\right)^2 \tag{21}$$

$$(\omega\theta)^2=2mn\theta\left(1+\frac{n\theta}{2m}\right) \tag{22}$$

The time vector diagram in Figure 7 shows the phase relationships between the input investment, production, and deliveries. It can be seen that the sum of mA and $-nK$ for these conditions produces a calculated output investment vector equal in phase and magnitude to the input vector.

The open loop gain or transfer function (ratio of calculated investment output to actual investment input) of this system is

$$G(j\omega\theta)=\frac{1}{j\omega\theta}\left[m-(m+n\theta)\epsilon^{-j\omega\theta}\right] \tag{23}$$

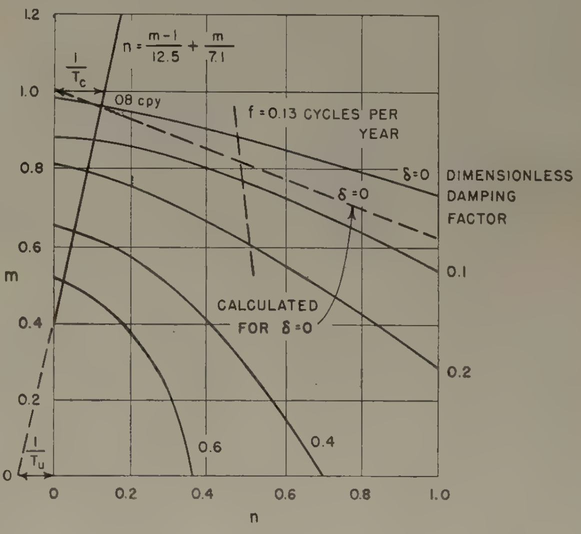

Figure 6. Stability of the economic analogue with three time constants, θ is 0.6 year

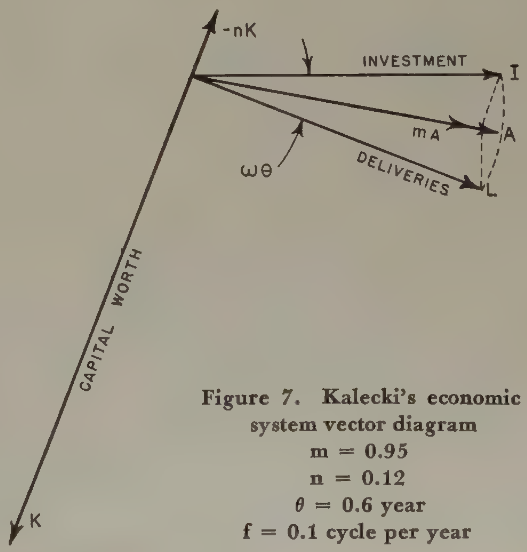

Figure 7. Kalecki's economic system vector diagram
m = 0.95
n = 0.12
θ = 0.6 year
f = 0.1 cycle per year

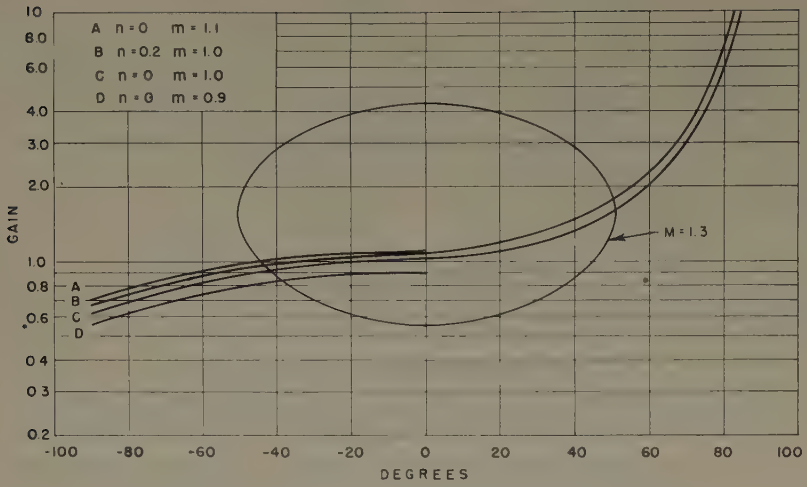

Figure 8. Open-loop transfer function of the system

Figure 5 shows a plot of equation 15 (the system parameters) and a plot of equations 20 and 22, marked $\delta=0$, which is the condition for sustained oscillations. The intersection gives the answers $m=0.95$, $n=0.13$, and a period of 9 years.

The depreciation time constant does not enter into the system. If m increases (increased credit or optimism) the system becomes much less stable and the frequency of oscillation diminishes slightly. If n increases, that is, the consumption time constant decreases, then the system becomes slightly less stable and the frequency of oscillation increases considerably. If the production time delay increases, the system becomes less stable and the frequency of oscillation decreases.

Figure 8 shows the plot of open loop gain on attenuation versus phase co-ordinates for several values of m and n. It can be seen that the horizontal trend of this curve resembles a pure dead time function, which is difficult to stabilize except by the introduction of a very long time constant. The long time constant should give an attenuation of 5 decibels at the resonant frequency. If T_s is the stabilizing time constant

$$T_s=2/\omega_0=\sqrt{2\theta T_c} \tag{24}$$

It should therefore be 1½ times the geometric mean of the production delay and the consumption time constant. A method of achieving this in the economic field is a separate investigation, but one word of caution should be introduced. Whatever the regulatory means that are proposed, whether legislative or by government manipulation of tax scales, permissible investments, subsidies, government contracts, and so forth, the investor is aware of these conditions, and adopts a new function for maximizing profit. This is a negative feedback closed loop, adjusting the parameters α and n, and has the function of almost completely cancelling out the effect of the proposed regulatory means.

Transients in a system as lightly damped as this will last for many cycles. In other words, the transient introduced by World War I is still essentially undamped, and that due to the Civil War is small but still significant. The events leading to World War II were the system response to previous transients, but the start of the war was a nonlinearity adding energy to the system, that is, a new transient. This model is an oversimplification, because it neglects the nonlinearities which are extremely important factors. Nevertheless, this linear model does display several of the basic reactions, and this rather unusual application of the electronic circuit analogue technique offers some interesting possibilities for the study of economic systems.

Appendix I

θ—Production lag in years
C—Personal consumption rate of capitalists, billions per year
U—Demanded rate of restoration of industrial equipment
A—Rate of production of capital goods
B—National income $=A+C$
I—Rate of investment orders
L—Rate of deliveries of investment orders
K—Total volume of existing industrial equipment, billions
m—$\partial I/\partial A$, increase of investment order rate with production rate (dimensionless)
n—$-\partial I/\partial K$, decrease of investment order rate with increase in total volume of existing equipment (positive parameter, units, reciprocal years)

Appendix II

P1 in Figure 3 should be adjusted so that the output $L-I$ is zero when switch *S2* is closed, switch *S1* opened, and a test signal introduced to the integrator. This is the subtractor balance adjustment. *P2* compensates for delay line attenuation; it should be set to make the magnitude of I equal the magnitude of L when the switch *S4* is down. *P3* introduces a secondary load on the audio transformer equivalent to that of the delay line. It should be adjusted to make the magnitude of I the same with switch *S4* either up or down. *P6* in Figure 4 is the m-loop gain adjustment. With m equal to 1, n equal to 0, and switch *S4* down, then *P4* should be adjusted until the open-loop gain equals 0.995 at 500 cycles per second, 2 volts. *P5* is the n-loop gain adjustment. With m equal to 0, n equal to 1, and switch *S4* down, then the open-loop gain should be adjusted to equal 1.6 at 500 cycles per second.

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The Electrical Nature of Corrosion and Cathodic Protection

H. D. HOLLER

THE CONSERVATION OF our natural resources has long been advocated. Because of the increasing demand for metals and the limited supply of most of them, the reduction of metal waste is of growing importance. A large part of this waste, variously estimated at several billion dollars annually, is the result of corrosion. The mitigation of corrosion is therefore a major phase of the problem of conserving our metal resources.

Estimates that several billion dollars worth of metal are lost annually due to corrosion underline the great importance of cathodic protection. This study of corrosion from the electrical standpoint is an evaluation of the behavior of galvanic couples in accordance with the laws of electricity.

Corrosion is essentially an electrochemical process; that is, a chemical reaction between the metal and its environment, involving the flow of electric current, in accordance with the laws of thermodynamics. The mitigation of corrosion therefore may be approached from the electrochemical or electrical point of view. The latter approach is particularly fruitful in the study of corrosion underground, underwater, or in chemical liquids where electrical measurements are feasible in the surrounding corrosive environment. Due to the advantages of electrical methods, perhaps more progress has been shown in these media than in other types of corrosion.

When a metal is in contact with a corrosive medium, differences in electric potential are established over the surface, due to inhomogeneities in the metal or surface environment, or both. As a result, there is a network of closed-circuit galvanic cells, or couples, in which electric currents flow from anodic areas to adjacent cathodic areas, corrosion occurring at the anodic areas in accordance with Faraday's laws. The rate of corrosion depends upon the characteristics of these galvanic couples, which are determined chiefly by the amount and type of polarization within them. If the cathodic areas can be polarized, by externally applied current, until their potential becomes equal to that of the corresponding anodic areas, then local galvanic currents and the equivalent rate of corrosion may be stopped completely. This is the principle underlying cathodic protection. While cathodic polarization of the metallic surface by external current is the means of achieving cathodic protection, its potential is the criterion by which it may be determined how much protection is obtained.

For the protection of iron, the criterion is approximately 0.8 volt with respect to the saturated calomel electrode. If, as in many cases, the minimum current required for complete protection is of the same order of magnitude as the sum of the local corrosion currents, then the amount of metal saved is of the same order, in terms of electrochemical equivalents, as that of the protective current required. This ordinarily may be considered as economical protection.

HISTORY

OVER A CENTURY ago Sir Humphry Davy recognized the electrochemical nature of corrosion of "His Majesty's ships of war" and demonstrated the cathodic protection of copper in sea water by the use of attached plates of the "more electropositive" metals, zinc and iron.[1–3] Thus began the application of the galvanic-cell principle of sacrificing one metal to preserve another. Only recently has an externally applied current become used widely for corrosion mitigation. Such is the importance of an economic stimulus which, in this case, developed soon after the burial of thousands of miles of bare cross-country pipe line early in the present century.

During the trolley-car age, the corrosion of pipe lines was attributed, in urban areas, to stray currents from electric power plants. Later, it was discovered that pipe lines far from all sources of stray current continued to corrode. This was found to be due largely to the character of the underground environment and partly also to the absence of stray current. The trolley, which supplied some cathodic protection, was belatedly recognized as a possible benefactor. The effectiveness of cathodic protection obtained by keeping the pipe line at a so-called negative potential[4,5] and a direct relation (Table I) between electric potential and pipe-line leaks were observed.[6]

Table I. Relation of Electric Potential to Leaks for Parallel Pipe Lines on the Same Right-of-Way

Line number 3 referred to as zero

Line Number	Average Potential Difference, Millivolts	Total Number of Leaks
3	0 (anodic)	155
4	+15	101
1	+26	100
2	+46	53
5	+82 (cathodic)	47

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Consequently, the mitigation of underground corrosion early became almost entirely a problem for the electrical engineer. More recently, attention has been given to the cathodic protection of ship hulls.[7]

Cathodic protection is not simply a matter of directing current toward a corroding structure. This is the means of accomplishing the purpose; but some criterion is needed to determine how much current is required for complete protection and how to avoid excessive current with consequent damage to coatings as well as waste of energy. The fundamental basis of such a criterion has been firmly established[8,9] but its usefulness depends upon an adequate understanding of the mechanism of cathodic protection and of the electrochemistry of the phase boundary of the metal concerned. The purpose of this article is to offer some contribution to such an understanding.

ELEMENTARY PRINCIPLES

MUCH OF THE controversy in this field of electrochemistry may be avoided if the terminology, common to such a borderline field, is understood. For this reason, some of the basic principles that underly the corrosion process are summarized here.

The corrosion of a metal may be defined as its conversion into one or more of its compounds, as the result of a chemical reaction at the phase boundary between the metal and its environment. Such a reaction is electrical in the sense that it involves an electric potential gradient at the boundary and a transfer of electrons in accordance with Faraday's law.

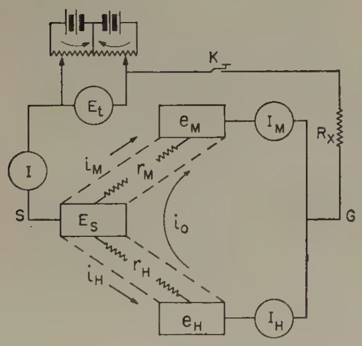

Figure 1. Electric circuit for study of a galvanic couple by application of external current I

An atom M at the surface of a metal in contact with an ionizing medium, such as water, tends to lose a number n of electrons and becomes a metal ion with an equal number of positive charges. Thus

$$M - n\epsilon^- \rightarrow M^{n+} \tag{I}$$

The metal is then an electrode, having a potential characteristic of the reaction, which reaches equilibrium if no electrons are allowed to enter or leave the system.

If, however, the metal is connected electrically to a second electrode having a different potential and in the same electrolyte, a galvanic cell on closed circuit is formed. Perhaps the most common example of a second electrode is that of the metal covered with atomic hydrogen which may be liberated on portions of the same metal surface. Then, if the electrons liberated in reaction I flow from the metal to the hydrogen electrode, the following reaction occurs

$$H^+ + \epsilon^- \rightarrow H \tag{II}$$

where H^+ = the hydrogen ion, and H = atomic hydrogen.

The essential condition for such a transfer of electrons is a difference in potential between the electrodes represented by reactions I and II. Conversely, any stoppage of electron flow, and therefore of the primary corrosion processes, requires that these electrodes be brought to the same potential, or that the electric connection between them be opened.

ELECTRODE POTENTIALS

THE POTENTIAL OF a metal or of a hydrogen electrode depends first on its inherent tendency to ionize, and second on the concentration of its ions already in the ionizing medium. Potentials of the different metals are given for normal ion concentrations in various published tables, called "electromotive force series," or "potential series," where the normal electrode potential is represented by E_0 and the "normal" hydrogen electrode is taken as zero. The usefulness of these tables for anticipating the corrosion behavior of a metal is limited because of the predominant effects of other factors which control the kinetics of the chemical reaction involved. However, by using such a normal potential E_0 as a reference point, it is possible to estimate the potential of a metal in an electrolyte, by the application of Nernst's law, if the ion concentration is known and the metal is free from a film having an electrode potential of its own. Thus, at 25 degrees centigrade

$$E_M = E_0 - 0.058 \log_{10}[M^{n+}] \tag{1}$$

and

$$E_H = E_0 - 0.058 \log_{10}[H^+] = 0 - 0.058 \log_{10}[H^+] \tag{2}$$

where E_M = electrode potential of metal with reference to the normal hydrogen electrode; $[M^{n+}]$ = metal ion concentration; n = number of electrons released in the ionization of an atom; E_H = electrode potential of hydrogen; and $[H^+]$ = hydrogen ion concentration (activity).

If E_M and E_H are the electrode potentials of the metal and hydrogen respectively, and are not changed by current flow, then

$$E_1 = E_M - E_H \tag{3}$$

Since log $[M^{n+}]$ is negative, when $[M^{n+}]$ is less than normal concentration, E_M may be increased by reducing $[M^{n+}]$. Similarly E_H may be increased by reducing $[H^+]$ as by addition of an alkali. If E_H becomes equal to E_M, the driving force E_1 = zero and corrosion stops.

VARIATIONS IN ELECTRODE POTENTIAL

THE ELECTRODE POTENTIAL varies not only with ion concentration, temperature, and other properties of the solution but also with the physical properties of the metal, such as crystalline structure, and with chemical modifications of the metallic surface, such as oxides.

As a result, electric currents flow from anodic areas, through the electrolyte, to cathodic areas, and the phase boundary becomes a complex network of closed galvanic-cell circuits.

An outstanding characteristic of electrode potentials in most corrosion cells is that they vary with current flow due to changing ionic concentrations or to other effects. For example, if such a cell, having an internal resistance r, is closed through an external resistance R, then the steady cell current i_0 will be given by Ohm's law. Thus

$$\frac{e_M-e_{\mathrm{H}}}{R+r}=i_0 \tag{4}$$

where

$$e_M=E_M-\Delta E_M \text{ and } e_{\mathrm{H}}=E_{\mathrm{H}}+\Delta E_{\mathrm{H}}$$

and $-\Delta E_M$ and ΔE_{H} are the changes in electrode potentials resulting from the flow of current i_0.

GALVANIC COUPLES

A GALVANIC CELL on the surface of a metal is short-circuited through the metal and constitutes a galvanic couple where the external resistance is usually negligible. Its internal resistance r may be high or low and localized at one or both electrodes. It is possible to consider r as consisting of two parts, r_M associated with the metal anode and r_{H} associated with the hydrogen cathode. Then if R is negligible, equation 4 becomes

$$\frac{e_M-e_{\mathrm{H}}}{r_M+r_{\mathrm{H}}}=i_0 \tag{5}$$

Mindful of the time effects, the resistances are assumed to be constant, and e_M and e_{H} to be the potentials of equipotential surfaces.

In the study of a galvanic couple (short-circuited cell), it is soon realized that there is little choice in measurement techniques. The most obvious procedure is the introduction of another electrode S into the cell for the purpose of making an electric connection. In so doing, two points are obtained where connections to an external circuit can be made: at electrode S, and at the metallic junction G between the elements of the couple (Figure 1). In reference to the external circuit, the elements of the couple are in parallel with each other.

If the potential difference between points S and G is measured with a potentiometer, the observed electromotive force is

$$(E_G-E_S)$$

where

$$E_G=e_M-i_0r_M \tag{6}$$

$$=e_{\mathrm{H}}+i_0r_{\mathrm{H}} \tag{7}$$

and E_S = the potential of a nonpolarizing reference electrode. Toward an external circuit, E_G acts like an electromotive force component, though a resistive potential difference, due to i_0, is included. The resistance of the couple toward an external current is[10]

$$R_G=\frac{r_M\,r_{\mathrm{H}}}{r_M+r_{\mathrm{H}}} \tag{8}$$

If an external electromotive force E_t is applied between points S and G, first, in opposition to (E_G-E_S), and current I (Figure 1) is observed, when $I=0$

$$E_t=(E_G-E_S) \tag{9}$$

This electromotive force is the same as that measured with a potentiometer.

Next, let $E_t>(E_G-E_S)$. Then by Ohm's law

$$E_t-(E_G-E_S)=I(R_X+R_G) \tag{10}$$

where R_X is all the resistance in the external circuit in series with the couple. That part of E_t which is applied to the couple is then

$$E=E_t-IR_X \tag{11}$$

Rewriting 10 yields

$$E=(E_G-E_S)+IR_G \tag{12}$$

That is, the application of the electromotive force E_t simply adds the resistive component IR_G. If the distribution of the applied current on each electrode is assumed to be the same as that of current i_0, then

$$E=(e_M-E_S)-i_0r_M+i_Mr_M \tag{13}$$

$$E=(e_{\mathrm{H}}-E_S)+i_0r_M+i_{\mathrm{H}}r_{\mathrm{H}} \tag{14}$$

where the resistive components i_Mr_M and $i_{\mathrm{H}}r_{\mathrm{H}}$ have been added to E_G, as defined in equations 6 and 7, and $i_Mr_M=i_{\mathrm{H}}r_{\mathrm{H}}=IR_G$.

If I_M and I_{H} represent the observed currents through the respective paths, then

$$I_M=i_M-i_0 \tag{15}$$

$$I_{\mathrm{H}}=i_{\mathrm{H}}+i_0 \tag{16}$$

Also,

$$\frac{E-(e_M-E_S)}{r_M}=I_M \tag{17}$$

and

$$\frac{E-(e_{\mathrm{H}}-E_S)}{r_{\mathrm{H}}}=I_{\mathrm{H}} \tag{18}$$

The study of a corrosion process from the electrical standpoint resolves itself into determining the characteristics of the galvanic couple involved, as indicated by its potential and its behavior toward external current; that is, its polarizability.

POLARIZATION WITHIN A GALVANIC COUPLE

POLARIZATION PLAYS an important role within a galvanic couple even when no current is entering or leaving it. This may be apparent in the graphic diagram (Figure 2) where the cell current flowing to the cathode is considered positive, $+i_0$, and from the anode is negative, $-i_0$.

The potential E_G of the couple is determined by the internal polarization, where $-\Delta E_M-i_0r_M$ = total anode polarization and $\Delta E_{\mathrm{H}}+i_0r_{\mathrm{H}}$ = total cathode polarization.

Thus, "polarization" comprises any change in electromotive force (ionic polarization) plus a resistive component; most measured values of polarization therefore include both.

In a critical study of polarization and its effects, it is

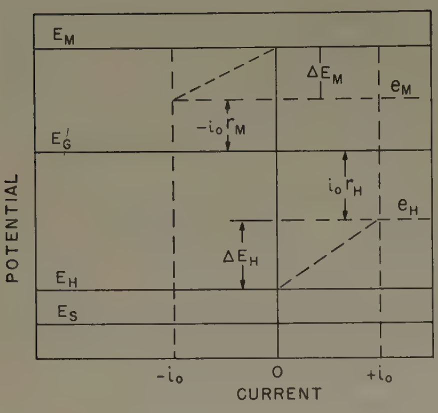

Figure 2. Electrical relations which define the potential E_G of a galvanic couple

important to appreciate the difference in nature between an electromotive force component and a resistive potential component. A potential difference due to electromotive force is a possible source of electric current, while a potential difference due to a resistance drop is the result of current flow. For example, $-\Delta E_M$ and ΔE_H are counter electromotive force components tending to drive current in opposition to i_0, thereby reducing the effective driving force in the circuit from $(E_M - E_H)$ to $(e_M - e_H)$.

The rate of corrosion at the anode, as represented by $-i_0$, is effectively limited by the total counter electromotive force $(\Delta E_H + \Delta E_H)$ as well as the resistance in the circuit. This principle by which the current flowing from the anode element is opposed by a counter electromotive force is part of the mechanism of cathodic protection, and may be augmented by applying external current to the couple. When this is done as in Figure 1, the polarization at each element partly determines the "partition" of the current received.

Before proceeding to evaluate the partition of current between the anodic and cathodic paths it is first necessary to decide upon the proper definition of partition. As shown by Müller[11,12] and others

$$\frac{i_M}{i_H} = \frac{r_H}{r_M} \tag{19}$$

But the current components i_M and i_H, not being measurable, are useful only in theoretical calculations. It is apparent from equations 17 and 18 that

$$\frac{I_M}{I_H} = \frac{E-(e_M-E_S)}{r_M} \times \frac{r_H}{E-(e_H-E_S)} \tag{20}$$

This is the true partition of current between the two paths, and represents the basic principle of current distribution over an electrode surface of nonuniform potential.[10]

Here, I_M and I_H are the algebraic sums of the component currents, and they can be measured directly in experimental couples. For demonstrating the reality of these currents, consider iron as the metal anode at potential e_M, and magnetite as the cathode at potential e_H (Figure 1). When K is open

$$-I_M = I_H = i_0$$

The cell-current i_0 flows from the iron through the electrolyte to the magnetite. As a result of this current, the cathode is covered with hydrogen and there is an Fe/H galvanic couple.

If K is closed and the applied voltage E_t is adjusted until $I=0$, then $E_t = (E_G - E_S)$ and again $-I_M = I_H = i_0$. Now if E_t is varied and currents I, I_M, and I_H are plotted against E Figure 3 results, where currents flowing to the cathode are indicated positive and those from the anode negative, and

$$E = E_t - IR_X \tag{11}$$

When $E > (E_G - E_S)$, I is positive, $-I_M$ decreases, and I'_H increases, as indicated.

When $E = (E_M - E_S)$, $I_M = 0$ and only the applied current I is now flowing to the cathode.

Then $I = I_H = I_p$ which is the current necessary to bring the potential of the cathode to the "open-circuit" potential E_M of the metal[8,9] and is called the minimum current required for cathodic protection.

If E is reduced to levels below $(E_G - E_S)$ then $-I_M$ increases and I_H decreases to zero when $E = (E_H - E_S)$.

Then $-I = -I_M = -I_q$, which is the current required to polarize the potential of the metal anode to $(E_H - E_S)$. Thus a diagram is obtained which shows the characteristic behavior of a galvanic couple toward external current. It consists of three "polarization curves": $I_M = f(E)$ for the iron element (anode); $I'_H = f(E)$ for the magnetite (hydrogen) element (cathode); and $I = f(E)$ for the couple.

The diagram in Figure 3 may also be constructed by determining the polarization curves for I_M and I_H separately. Then by connecting the two electrodes together electrically, the polarization curve for I can be obtained. These graphs are not usually straight lines, but frequently consist of a sequence of almost straight lines of different slopes. For example, using an Fe/Fe_3O_4 couple in wet clay, the polarization curve for I consists of straight lines intersecting at $I=0$, $I=I_p$, and $I=I_q$. An interesting relation, also pointed out by others,[11,12]

$$i_0 = \frac{I_p I_q}{I_p + I_q} \tag{21}$$

may be derived[10] algebraically or trigonometrically from Figure 3. In the Fe/Fe_3O_4 couple, i_0 computed from equation 21, agrees very closely with observed values of I_M and I_H when $I=0$.

CATHODIC PROTECTION

It is apparent in Figure 3 and equations 17 and 18 that the direction of the current in either path depends only on the relative magnitudes of the applied electro-

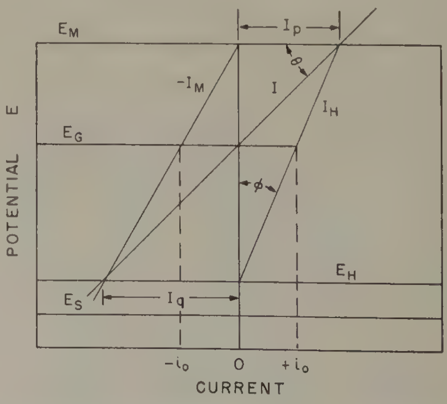

Figure 3. Polarization curves showing electrical characteristics of a galvanic couple

motive force E and the counter electromotive force in that path. For example, I_M, I, or I_H are all positive when E exceeds (E_M-E_S), (E_G-E_S), or (E_H-E_S), respectively, regardless of the magnitudes of r_M and r_H. If $E>(E_G-E_S)$ but $<(E_M-E_S)$, current I will flow from S only to the cathode and increase cathodic polarization.

When $E=(E_M-E_S)$, $I_M=0$ and cathodic protection is complete. This equality of applied electromotive force and counter electromotive force of the anodic element of the galvanic couple may be taken as a criterion for the condition of cathodic protection. It should be emphasized that while an equilibrium of electromotive forces is achieved, the result is accomplished only by applying the minimum protective current I_p. Potential is the criterion, but current is the means of cathodic protection. If $E>(E_M-E_S)$, I_M also becomes positive and both elements of the couple are then cathodic, the electrical relations still being expressed by equation 20.

The current patterns, complying with Kirchoff's laws, are given in Figure 4 for different relative values of E and the other electromotive forces in the circuit (Figure 1), where E_S serves a double purpose as auxiliary electrode for conducting I to or from the couple, and also as reference electrode.

The minimum value of E, and the corresponding current required for complete cathodic protection is indicated by pattern *c*, and "overprotection" by pattern *d*.

On the other hand, patterns *e*, *f*, and *g* represent acceleration of corrosion by increasing $-I_M$. For the pattern *f* and current $-I_q$, corrosion may be expected to proceed with "100-per-cent efficiency," in accordance with Faraday's law. Thus

$$W=I_qKt \tag{22}$$

where W=weight of metal converted; I_q=current; K=electrochemical equivalent of the metal; and t=time.

It therefore may be possible to reduce corrosion to a minimum by cathodic protection; or to increase it to 100 per cent by anodic polarization. The latter is not of interest here except for test purposes, as in the estimation of I_q.

Figures 3 and 4*c* indicate that cathodic protection is achieved when

$$E=(E_M-E_S) \tag{23}$$

The electromotive force (E_M-E_S) is generally known, or may be estimated from existing data. Also

$$E=(E_G-E_S)+IR_G \tag{12}$$

where R_G=the resistance of the couple. From equations 23 and 12 is obtained

$$(E_M-E_S)=(E_G-E_S)+IR_G \tag{24}$$

for the condition of cathodic protection.

If IR_G is negligible

$$(E_M-E_S)=(E_G-E_S) \tag{25}$$

and the problem of determining when cathodic protection is complete is simplified. It is then only necessary to measure (E_G-E_S) by one of several possible methods[13] while the applied current I is being increased, until the equality, equation 25, is attained. For example, in the case of iron in water the open-circuit potential E_M, referred to the saturated calomel electrode, E_S, is about 0.82 volt. Cathodic protection is then complete when $(E_G-E_S)=$ 0.82 volt.

If IR_G is an appreciable quantity, and the result of measurement of (E_G-E_S) is used in equation 25 instead of 24, the difference, IR_G, represents "overprotection." That is, the use of the equality in 25 may result in an error on the side of safety. Therefore, whether IR_G is negligible or not, the measurable quantity (E_G-E_S) serves as a valuable index to the cathodic protection being obtained from a given applied current.

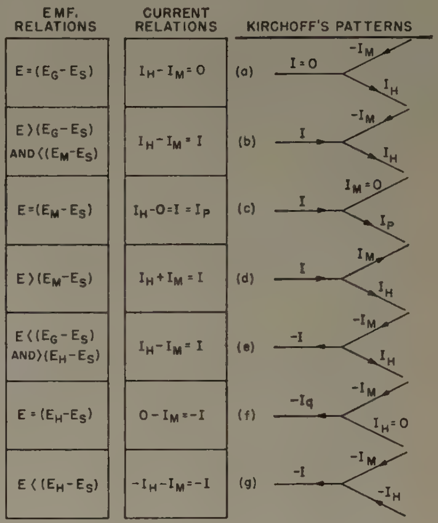

Figure 4. Some electrical relations within a galvanic couple obtained by variation in applied voltage E

CATHODIC PROTECTION APPLIED TO IRON

NO DOUBT, the greatest application of cathodic protection is in the case of iron underground and underwater, where aeration is restricted. The value of E_M for iron under these conditions may be taken as that corresponding to the electrode processes represented by reactions I and II, in equilibrium. For example

$$Fe \rightarrow Fe^{++}+2\epsilon^- \tag{III}$$

$$H_2O \rightarrow H^++OH^- \tag{IV}$$

$$2H^++2\epsilon^- \rightarrow 2H \rightarrow H_2 \tag{V}$$

$$Fe^{++}+2OH^- \rightarrow Fe(OH)_2 \rightarrow Fe(OH)_2 \tag{VI}$$

where the concentration of hydrogen ions [H$^+$] is about $10^{-9.5}$ gram-ion per liter (pH=9.5). This is computed from the solubility product of $Fe(OH)_2$, taken from the literature,[14] the corresponding concentration of (Fe^{++}) being $10^{-4.5}$ gram-ion per liter. At these ion concentrations, the electrode potentials of iron (III) and of hydrogen (V) are approximately equal. That is, $(E_{Fe}-E_S)=(E_H-E_S)=0.82$ volt where E_S is the electrode potential of a saturated calomel electrode. This defines the potential necessary for the cathodic protection of iron, as related to the hydrogen ion concentration or pH. This is in accordance with observations many years ago[15] on the reaction of iron with water. In the absence of air and at room temperature, this reaction with the evolution of hydrogen became negligible at a pH of 9.4 to 9.6 in 47 different soils, having initial pH values ranging from about 4 to 9. On the basis of these relations, theoretical and experimental, cathodic protection may be considered as accomplished when the current can maintain a pH of about 9.5 at the iron surface.

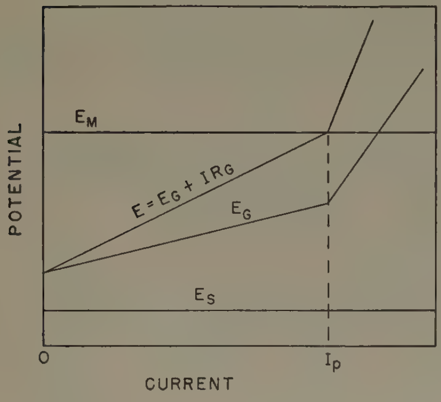

Figure 5. Relation of potential E_G of galvanic couple to the resistance R_G of the couple when cathodically polarized by external current I

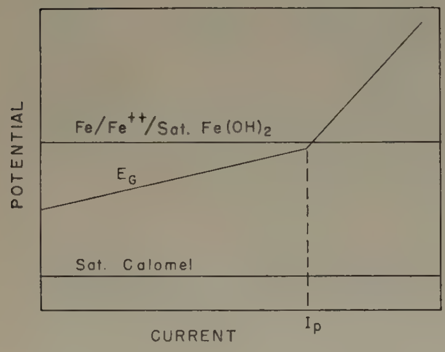

Figure 6. Relation of "break" in polarization curve for iron to the open-circuit potential of iron

For other metals, the requirements for cathodic protection are based on these principles but must be established specifically for each metal and environment in a manner similar to that used for determining the criteria in the case of iron.

SIGNIFICANCE OF HYDROGEN OVERVOLTAGE

If the polarization of the iron-hydrogen couple is increased further, after cathodic protection is accomplished, Figure 4*d*, hydrogen evolution may be expected. Thus, in Figure 5 when E exceeds E_M, the phenomenon of hydrogen overvoltage may manifest itself as a "break" in the I=f (E) graph, or the I=f (E_G) graph. If IR_G is negligible, the two graphs will coincide, and the measured value of E_G is then a true index to cathodic protection and the evidence of hydrogen overvoltage is a confirmation of this fact.

Whether a break is perceptible depends upon the relative electrode areas and the shape of the composite polarization curve, for applied current below and above the break. When the break occurs at a potential which coincides closely with E_{Fe}, the evidence is doubly convincing that $E_G=E_{Fe}$ and that cathodic protection is attained.

Thus in a specific case, the results of which are illustrated in Figure 6, a steel tube was immersed in a 0.1-per-cent solution of sodium chloride. A parallel anode was used to distribute the current uniformly along the tube. A saturated calomel electrode placed at intervals along the tube was used as reference and (E_G-E_S) was measured for different currents. The near coincidence between the break in the polarization curve and E_{Fe} (0.82 volt) indicates that IR_G was negligible. Under these conditions, I_p is correctly indicated by a break when potential is plotted as a function of I.

MULTIPLE GALVANIC COUPLES

Thus far, the metal/hydrogen couple has been used to illustrate the fundamental electrical mechanism of corrosion and the role of hydrogen in the process. That of oxygen is also of great practical importance.

Since oxygen tends to depolarize the cathode, the level of E_G is thereby lowered. For example, in Figure 7 are two metal/hydrogen galvanic couples, *a* being oxygen-free and *b* having been lowered in potential by oxygen or some other cathodic depolarizer. If these two couples are electrically connected, current I' flows from *a* to *b*, the latter receiving some cathodic protection. Obviously, this protection cannot be complete, since this would require that the source of current be at a potential E_G higher than E_M. Nevertheless, corrosion is reduced somewhat in the

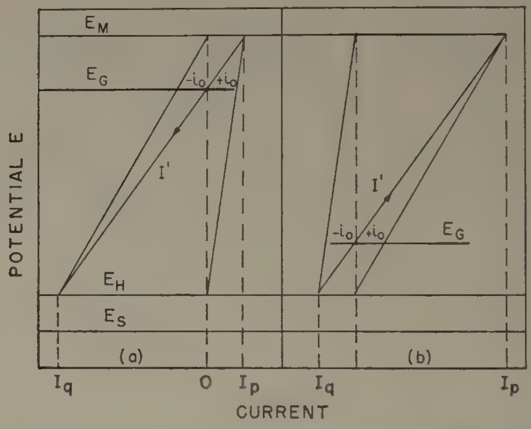

Figure 7. Galvanic-couple characteristics of a metal determined by: (a) "cathodic control" and (b) anodic control

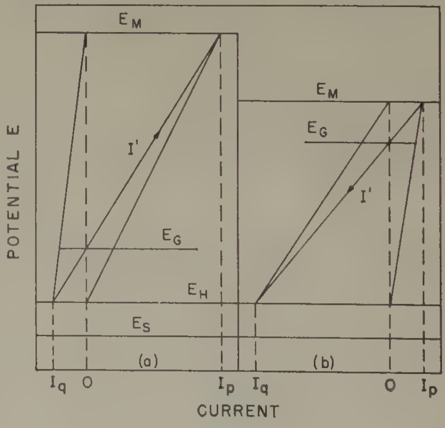

Figure 8. Galvanic-couple characteristics of one metal (a) under anodic control and another metal (b) under cathodic control

aerated area at the expense of the metal in the unaerated area.

Whenever the anodic polarization in a galvanic couple is dominant, the potential of the couple E_G is nearer E_H. Thus, in Figure 7*b*, the steeper the anodic polarization graph is, the smaller i_0 becomes. If i_0 is negligible, anodic passivity is the result. Conversely, if cathodic polarization dominates within the couple and E_G approaches E_M so closely that i_0 becomes negligible, then cathodic passivity results. All known cases of passivity may be explained on the basis of the galvanic-couple theory of corrosion.[16]

The appearance of a break in a cathodic polarization curve due to hydrogen overvoltage is more likely to be graphically perceptible in the second case where the couple is under cathodic control.

Similar relations may exist between galvanic couples involving different metals. For example, Figure 8*a* represents a metal having a higher E_M value than *b*. However, due to the electrical characteristics of the couple, of which metal *a* is a part, the potential of E_G in *a* is lower than E_G for metal *b*. Therefore, if *a* and *b* are electrically connected *I* will flow from *b* to *a*, the latter receiving some cathodic protection from *b*. In certain environments, *a* might represent aluminum being protected at the expense of zinc, represented by *b*. In other cases, like zinc/iron, iron/tin, and iron/aluminum, the polarity of the couple depends upon conditions where the metals act, not as individual metals, but as galvanic couples, the cathodic elements or their oxides covered with hydrogen serving as hydrogen cathodes.

SUMMARY

THE PRIMARY STEPS in the corrosion process are shown to be those occurring in a galvanic couple, that is, a galvanic cell on closed circuit. The study of corrosion from the electrical standpoint therefore consists in the evaluation of factors controlling the behavior of galvanic couples, in accordance with the laws of electricity.

The mechanism of cathodic protection is that of cathodically polarizing a galvanic couple by an external current.

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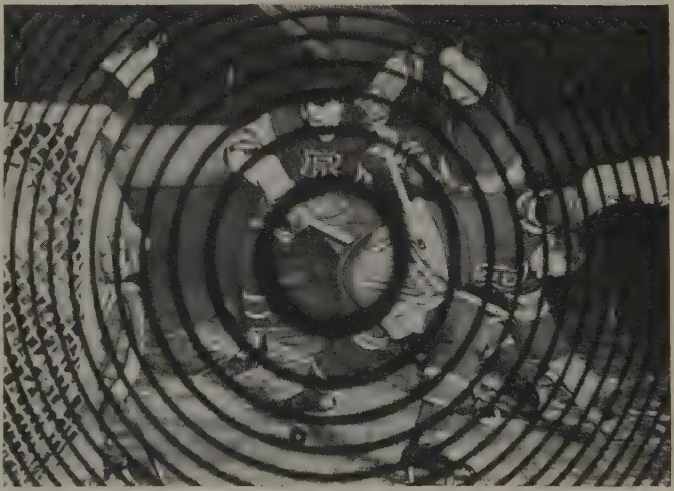
Military Gunsight Proves Fast TV Camera Finder



A military gunsight, developed by the Polaroid Corporation, Cambridge, Mass., and used on antiaircraft guns, recently has come to the aid of the television cameraman for fast pin-pointing in rapid action shots. Known as the Polaroid Optical Ring Sight, the finder looks like an ordinary camera filter, but when he looks through it, the cameraman sees a pattern of concentric circles on the scene. The cameraman does not have to line up his eye with the sight. Anything he sees inside the center ring will be centered accurately on the television screen. It consists of a single glass-faced disk so constructed that a set of concentric rings appears at target distance in the field of view. The sight is complete in itself, requiring no auxiliary illumination or accessories. The rings themselves appear in color; the center ring is dark maroon and purple, approximating black, the outer rings in lighter colors. The outer rings are spaced progressively closer and decrease progressively in contrast, so that rings beyond the fourth or fifth are substantially invisible, leaving the field clear for observation.

INSTITUTE ACTIVITIES

Tentative Technical Program Released for AIEE South West District Meeting

Featuring papers and discussions on "Research Development and Utilization of Electric Energy," the tentative technical program has been released (pages 375–76) for the AIEE South West District Meeting to be held in St. Louis, Mo. As announced in the March issue (*pp 280–1*), the meeting will be held at the Jefferson Hotel, April 15–17.

In addition, student sessions are being planned for Washington University in St. Louis, April 18 and 19. Advance registration is urged and identification badges for those who register in advance will be available at the registration desk. The desk will be open beginning on the afternoon of April 14. A registration fee of $2 will be charged all members, and a fee of $3 will be charged nonmembers. No fee will be required of enrolled students or the immediate families of members.

STUDENT ACTIVITIES

Students are encouraged to attend the sessions of the District meeting prior to their regular sessions, and are welcome to attend any of the social functions. A tentative program for their own meeting at Washington University indicates the following activities:

Technical Paper Sessions

Friday, April 18
Graham Chapel, Washington University

Saturday morning, April 19
Graham Chapel, Washington University

Committee Meetings

Friday noon, April 18
Student Branch Chairmen's Meeting Luncheon
District Student Counselors Meeting Luncheon

Banquet

Saturday noon, April 19
Banquet and Award of District Student Paper Prizes

Students should register at the Jefferson Hotel, April 15–17.

INSPECTION TRIPS

One of the features of the meeting will be inspection trips to points of interest in St. Louis:

Anheuser-Busch, Inc. (Wednesday, April 16, 1:30 p.m.; fee, $1). Anheuser Busch, Inc., founded in 1852, has a plant area of 110 acres, or 70 city blocks. The various buildings contain floor space of 5,000,000 square feet where 7,000 employees produce 6,000,000 barrels of beer per year. Seventeen bottling lines package 4,500,000 bottles and eight canning lines, 2,000,000 cans per day. The shipping facilities can accommodate 166 railroad cars simultaneously. By the middle of this year, the steam generating capacity will be 920,000 pounds per hour in six boilers. The present peak steam load is 600,000 pounds per hour, and the electric generating capacity is 29,825 kva, with a peak load of 17,500 kw. Installed refrigeration capacity is 7,300 tons, with an ice plant capacity of 168 tons per day. The water works can pump 7,250,000 gallons per day.

Meramec Plant (Thursday, April 17, 1:00 p.m.; fee, $2). Meramec plant, currently under construction, is the latest addition to the Union Electric System. The plant is located at the confluence of the Mississippi and Meramec Rivers about 12 miles south of St. Louis. The initial installation consists of two steam units each rated 110,000 kva directly connected to transformers which step up the generator voltage from 16,500 to 138,000 for delivery to the system. Plant coal will be received by barge, and the necessary unloading facilities will be located on the property. Commercial operation of the first unit is scheduled for the end of 1952 and the second unit about a year later. No equipment will be operating in April. The turbine, generator, boiler, coal handling equipment, transformers, and auxiliary switchgear will be in the process of installation at the time of the inspection trip.

ENTERTAINMENT

The smoker, to be held in the Jefferson Hotel's Gold Room on Tuesday evening, April 15, will provide an opportunity for the visiting delegates to be together for an evening, and includes dinner and entertainment. Also, there will be a pre-smoker gathering in the Ivory Room starting at 5:30 p.m. The price of the tickets will be $6 per person and tables seating eight persons will be available. Reservations should be made through George S. Whitlow, Chairman, Smoker Committee, c/o Union Electric Company of Missouri, 315 North 12th Boulevard, St. Louis 1, Mo. Checks should be made payable to the "AIEE Smoker Committee."

The dinner-dance, which has been scheduled for Wednesday evening in the Gold Room, promises to be the outstanding social event of the meeting. Tables seating eight are available for the dinner. Reservations at $6 per plate will be accepted by James E. Smith, Chairman, Dinner-Dance Committee, c/o Westinghouse Electric Corporation, 411 North Seventh Street, St. Louis 1, Mo. Checks should be made payable to the order of the "AIEE Banquet Committee."

For further entertainment information, as well as complete details concerning hotel reservations in St. Louis, see the March issue. At the meeting, information on all features may be obtained at the registration desk. The bulletin board near the desk will contain notices concerning time and point of departure of all inspection trips and other data of general interest.

Future AIEE Meetings

South West District Meeting (*page 374*)
Jefferson Hotel, St. Louis, Mo.
April 15–17, 1952
(*Final date for submitting papers—closed*)

Joint AIEE-AWS-IEESD Welding Conference (*page 376*)
Rackham Memorial Building, Detroit, Mich.
April 16–18, 1952

AIEE Textile Conference (North) (*page 383*)
Philadelphia Textile Institute, Philadelphia, Pa.
April 24, 1952

AIEE Conference on Rubber and Plastics
Potage Hotel, Akron, Ohio
April 28, 1952

North Eastern District Meeting (*page 377*)
Arlington Hotel, Binghamton, N. Y.
April 30–May 2, 1952
(*Final date for submitting papers—closed*)

AIEE Textile Conference (South) (*page 383*)
Georgia Institute of Technology, Atlanta, Ga.
May 1–2, 1952

Joint AIEE-IRE-RTMA Conference on Progress in Quality of Electronic Components (*page 379*)
Roger Smith Hotel, Washington, D. C.
May 5–7, 1952

AIEE Conference on Domestic Appliances
Engineering Society's Building, Cincinnati, Ohio
May 16–17, 1952

AIEE Conference on Electronic Converter Applications and Tubes (*page 383*)
William Penn Hotel, Pittsburgh, Pa.
May 19–20, 1952

Summer General Meeting (*page 380*)
Hotel Nicollet, Minneapolis, Minn.
June 23–27, 1952
(*Final date for submitting papers—closed*)

Pacific General Meeting
Phoenix, Ariz.
August 19–22, 1952
(*Final date for submitting papers—May 21*)

AIEE Participation in Centennial of Engineering
Congress Hotel, Chicago, Ill.
September 10–12, 1952
(*Final date for submitting papers—June 10*)

Fall General Meeting
New Orleans, La.
October 13–17, 1952
(*Final date for submitting papers—June 13*)

Middle Eastern District Meeting
Commodore Perry Hotel, Toledo, Ohio
October 28–30, 1952
(*Final date for submitting papers—July 30*)

Tentative Technical Program

South West District Meeting, St. Louis, Mo., April 15-17

Tuesday, April 15

10:00 a.m. General Session

H. R. Fritz, Vice-President, District 7, presiding

Address: Our Heritage From Engineering Education. *President F. O. McMillan*

Address: Research, Development, and Utilization of Electric Power. *J. B. Thomas*, President and General Manager, Texas Electric Service Company, Fort Worth, Tex.

2:00 p.m. Industrial Power Utilization

W. J. Roa, presiding

DP. Development of the Anheuser-Busch Electric System.** *W. J. Steiling*, Anheuser-Busch, Inc.

DP. Industrial Power Utilization From the Utility Standpoint.** *P. W. McCormick*, Union Electric Company of Missouri

DP. Operation and Experience With Heat Pumps in St. Louis.** *G. S. Whitlow*, Union Electric Company of Missouri

DP. Development of the Aluminum Ore Electric System.** *M. B. Keen*, Aluminum Ore Company

2:00 p.m. Power Stations

E. L. Hough, presiding

DP. Application of Shunt Reactors at Generating Plants.** *J. M. Dyer, Jr.*, Public Service Company of Oklahoma

DP. Meramec Plant of Union Electric Company.** *I. F. Krughoff, W. G. Clover, R. G. Mueller*, Union Electric Company of Missouri

DP. An Electronic Control for Distribution Voltage Boosting Devices and Similar Step Regulators.** *John Zaborszky, J. W. Rittenhouse*, Missouri School of Mines and Metallurgy

51-371. Sensitive Ground Relaying of A-C Generators. *E. T. B. Gross*, Illinois Institute of Technology. Presentation by title only for discussion

2:00 p.m. Aircraft Electric Equipment I

G. E. Sylvester, presiding

52-131. A New Circuit Breaker for Aircraft Electric Systems, 40 to 125 Amperes, 120 Volts A-C or D-C. *B. S. Beal III, P. J. Reifschneider*, General Electric Company

DP. Preventive Maintenance Aids Large Aircraft A-C System Progress.** *J. K. Howell*, Westinghouse Electric Corporation; *Captain P. E. Burket*, United States Air Force

DP. Electronic Equipment Installation in Fighter Aircraft.** *A. R. Anderson*, McDonnell Aircraft Corporation

52-132. Distribution System Reliability of 28-Volt D-C Aircraft Electric Systems. *K. W. Carlson, E. S. Sherrard*, General Electric Company. Presentation by title only for discussion

52-133. Weight Analysis of Aircraft Actuators. *H. M. Geyer, R. C. Treseder*, General Motors Corporation. Presentation by title only for discussion

52-134. Reduced-Voltage D-C Motor Controllers for Aircraft. *H. J. Finison, W. C. Andersen*, Armour Research Foundation. Presentation by title only for discussion

Wednesday, April 16

9:30 a.m. Aircraft Electric Equipment II

R. S. Mead, presiding

52-135. Unit Equipments for Aircraft Electric Power Systems. *H. J. Finison*, Armour Research Foundation

52-136. Study of Aircraft Cooling Systems for Rotating Electric Equipment. *C. G. Martin*, Jack and Heintz, Inc.

52-137. Intermittent Faults in Aircraft Electric Systems. *L. R. Larson, M. Trbovich, P. E. Toomire*, Naval Research Laboratory

52-138. Characteristics of Faults on Aircraft Electric Systems. *L. R. Larson*, Naval Research Laboratory. Presentation by title only for discussion

52-139. Short-Circuiting Techniques to Deactivate a Generator After a Fault. *O. Markowitz, J. W. Pobst*, United States Naval Air Development Center. Presentation by title only for discussion

52-144. Stopping Devices for 400-Cycle Motors. *L. A. Zahorsky*, Lear, Inc. Presentation by title only for discussion

52-141. Continuous Current and Temperature Rise in Aircraft Cables. *Milton Schach*, Naval Research Laboratory. Presentation by title only for discussion

52-142. Effects of Terminal Voltage, Load Current, and Minimum Rotor Speed on the Weight of D-C Aircraft Generators. *D. H. Scott*, Naval Research Laboratory. Presentation by title only for discussion

9:30 a.m. Transmission and Distribution I

O. S. Hockaday, presiding

DP. Application and Operation of Switched Capacitors for System-Wide Requirements.** *B. M. Gallaher*, Texas Electric Service Company

DP. Expanding the Frontiers of Capacitor Economics.** *P. E. Hendrickson, V. A. Rydbeck*, General Electric Company

DP. Complex Multiplication of General Circuit Constants.** *R. D. Goodrich, Jr.*, Bureau of Reclamation

52-143—ACO.* Load Pickup After Extended Outage. *A. W. Edwards, L. V. Chabala*, Westinghouse Electric Corporation

—PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained from AIEE Order Department, 33 West 39th Street, New York 18, N. Y., as noted in the following paragraphs.

—PRICES of papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Technical Program Committee ultimately will be published in Proceedings and Transactions; also, each is scheduled to be published in Electrical Engineering in digest or other form.

9:30 a.m. Electric Machinery I

J. L. Hamilton, presiding

DP. Resistance Characteristics of Squirrel-Cage Rotor End-Rings.** *R. J. W. Koopman*, Washington University

52-144. Temperature Differentials in Single-End Ventilated Integral-Horsepower Motors. *C. P. Potter*, Wagner Electric Corporation

DP. Recent Trends in Modern Control Designs.** *E. H. Alexander*, General Electric Company

52-145. Maintenance and Operating Experiences—Diesel-Electric Locomotives. *C. H. Griffith, E. H. Pfeil*, Missouri-Kansas-Texas Lines

9:30 a.m. Sciences and Electronics

J. W. Rittenhouse, presiding

52-146. Synthesis of 2-Terminal Pair Networks. *Robert Kahal*, Washington University

DP. Recent Developments in Transistors.** *J. A. Morton*, Bell Telephone Laboratories, Inc.

52-147—ACO.* A Special Dynamometer for Testing Small Motors. *S. H. Van Wambeck*, Knapp-Monarch Company; *W. A. Stein*, United States Naval Postgraduate School

DP. Magnetic Amplifier Applications.** *V. H. Krummenscher*, Vickers Electric Division

2:00 p.m. Transmission and Distribution II

C. W. Schemm, presiding

DP. Higher Transmission Voltages—Developments and Trends in United States and Abroad.** *P. L. Bellaschi*, Portland, Oreg.

DP. Engineering Features of Union Electric 138-Kv Development.** *G. S. Whitlow, Ren Beatty, T. D. Maintz*, Union Electric Company of Missouri

52-148. Determination of Inductive and Capacitive Unbalance for Untransposed Transmission Lines. *R. F. Lawrence, D. J. Povejsil*, Westinghouse Electric Corporation

DP. The 230-Kv Southern Illinois Transmission-Line Project.** *L. T. Byars* (deceased), Union Electric Company of Missouri; *R. H. Osborne*, Sverdrup and Parcel, Inc.

2:00 p.m. Electric Machinery II

P. G. Wallace, presiding

DP. Magnetic Noise in Salient-Pole Synchronous Machines.** *W. L. Ringland*, Allis-Chalmers Manufacturing Company

DP. Gas Turbine and Its Possible Applications.** *B. G. Hatch*, General Electric Company

DP. Feeder Voltage Regulators Save Critical Materials.** *W. L. Peterson*, Allis-Chalmers Manufacturing Company

52-149—ACO.* Economics of Distribution-Type Transformers. *H. F. Ostman*, Union Electric Company of Missouri; *W. A. Sumner*, Westinghouse Electric Corporation

2:00 p.m. Computing Devices

L. M. Haupt, presiding

DP. Introduction to Electrostructural Analysis.** *Randolph Blumberg*, Southwest Research Institute

DP. Operating and Economic Features of the 60-Cycle Impedance Phase-Shift Analyzer.** *E. B. Phillips*, University of Kansas

DP. Advantages of High-Frequency Operation of Network Analyzer.** *M. A. Faucett, J. D. Ryder*, University of Illinois

DP. Method for Solving the Hydraulics of a Grid-Iron Pipe System on a D-C Calculating Board.** *L. C. Austill*, Shell Oil Company

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* ACO: Advance copies only available; not intended for publication in *Transactions*.

** DP: District paper; no advance copies are available; not intended for publication in *Transactions*.

Thursday, April 17

9:30 a.m. Symposium on Loss of Generator Field

R. F. Danner, presiding

DP. Loss-of-Field Protection for Synchronous Generators.** *J. E. Barkle*, Westinghouse Electric Corporation

DP. Loss of Excitation Experience on Oklahoma Gas and Electric Company System.** *A. W. Walton*, Oklahoma Gas and Electric Company

DP. Experience With Loss of Field on Synchronous Machines Involving the Kansas City Power and Light Company System.** *D. H. Cameron, E. L. Mueller*, Kansas City Power and Light Company

DP. The Application and Operating Experience With Loss-of-Generator-Excitation Relays.** *C. R. Mason*, General Electric Company

9:30 a.m. System Operation

E. E. George, presiding

DP. From Wire to Microwave on the Union Electric System.** *P. T. Ramey, C. W. Blood*, Union Electric Company of Missouri

DP.* A Classification of Outages of Facilities in Electric Power Systems. *Arnold Rich*, Federal Power Commission

DP. Modern Railroad Communications and Signaling.** *R. M. Laurenson*, St. Louis and San Francisco Railroad

DP. Contemporary Train Radio Equipment Design.** *L. E. Verbarg*, Missouri-Pacific Railroad

9:30 a.m. Power System Protection

C. M. Lytle, presiding

DP. High-Speed Relaying.** *L. F. Kennedy*, General Electric Company, to be presented by C. R. Mason, General Electric Company

DP. Surge Protection of Dry Insulated Equipment.** *R. C. Dickinson, G. L. Moses, R. L. Schwab, Edward Beck*, Westinghouse Electric Corporation

DP. The Influence of Power System Design on Protective Relaying.** *J. L. Blackburn*, Westinghouse Electric Corporation

DP. Plains Lightning of the Middle West.** *D. D. Clarke*, Kansas City Power and Light Company

2:00 p.m. Engineering Education

A. S. Langsdorf, presiding

DP. Tomorrow's Engineer—in Preparation.** *K. B. McEachron, Jr.*, General Electric Company

DP. Tomorrow's Engineer—in Use.** *Guy Kleis*, Westinghouse Electric Corporation

2:00 p.m. Communications

W. B. Stephenson, presiding

DP. Exploitation of Message Statistics.** *B. M. Oliver*, Bell Telephone Laboratories, Inc.

DP. New Instrumentalities for the Short-Haul Toll Telephone Plant.** *H. R. Huntley*, American Telephone and Telegraph Company

52-150. Design of Low-Frequency Constant Time Delay Lines. *C. M. Wallis*, University of Missouri

DP. The Responses of Certain Basic Circuits to a Triangular Pulse.** *K. G. Black, T. J. Higgins*, University of Wisconsin

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Third Annual Welding Conference to Feature Techniques and Demonstrations

A broad-gauge inquiry into all aspects of present-day modern welding techniques and problems characterizes the program for the third annual Welding Conference to be held at Rackham Memorial Building, Detroit, Mich., on April 16, 17, and 18.

The conference is under the sponsorship of three technical groups, the AIEE, the Detroit Section of the American Welding Society (AWS), and the Industrial Electrical Engineers Society of Detroit (IEESD).

Three areas of interest will be found at the conference: (1) Technical papers giving the newest developments in arc and resistance welding; (2) discussion and interchange of information with other experts in the field including equipment makers, research technicians, and users; and (3) actual demonstrations of new machines and new techniques. In past years, the conferences have proved highly worth while for all who attended and the plans this year call for the same high standard.

Demonstration sessions are scheduled Thursday and Friday evenings from 5:30 to 10:00 p.m. The Friday evening session will be open to all members and guests. Admission to the Thursday evening session is by badge. The exhibit will include the latest electronic controls for all types of electric resistance and arc welders, and demonstrations will be given of several types of welders using these controls.

Registration: Please register in advance; registration fee is $3.00. Registration begins at 8:30 a.m. on Wednesday, April 16.

Conference Proceedings: Papers and discussions will be published in bound volume form. Copies may be ordered at $3.50 each at the conference or in advance by using the registration form. A very limited number of copies of the proceedings books for the first and second conferences are also available from R. S. Gardner at AIEE Headquarters, 33 W. 39th Street, New York 18, N. Y.

Hotel: Rooms are available at the Detroit Leland Hotel for those who register early.

Meals: Arrangements have been made for meals in the Rackham Memorial Building for those who make reservations and pay in advance. These meals have been prearranged at cost because nearby facilities are very limited and usually crowded.

Power Supply for Resistance Welding Machines: This report has been in preparation for several years and will be available for sale at the conference at $1.00 each.

Technical Program

Joint AIEE-AWS-IEESD Welding Conference
Detroit, Mich., April 16-18, 1952

Wednesday, April 16

9:30 a.m.

Welcome. C. H. Jennings President, American Welding Society, Westinghouse Electric Corporation, introduced by K. Sheren, Swift Electric Welder Company

Opening of Conference. C. N. Clark, Chairman, AIEE National Committee on Electric Welding, Duquesne Light Company

Quality Control

Chairman: C. B. Stadum, Westinghouse Electric Corporation

Session Secretary: J. F. Randall

Elements of Quality Control in Spot-Welding Aluminum for Aircraft. *F. H. Matthews*, Boeing Airplane Company

Military Aeronautical Spot and Seam Welding Specifications. *J. Maltz, N. E. Promisel*, Bureau of Aeronautics, Department of the Navy

Industry's Answer to ANW Specifications. *P. F. Parks*, Solar Aircraft Company

Industry's Answer to ANW Specifications. *F. Brandt*, Thomson Electric Welder Company

2:00 p.m. Instrumentation

Chairman: R. E. Young, Public Service Company of Northern Illinois

Session Secretary: C. R. Dixon

Resistance-Welding Instrumentation—Past, Present, and Future as Applied to Quality Control. *Reidar P. C. Rasmusen, Robert C. McMaster*, Battelle Memorial Institute

Instruments to Improve the Operation of Single-Phase and 3-Phase Resistance Welding Machines. *William R. Stern*, Brush Development Company

New Devices for Measurement of Welder Voltage Drops on a Power System. *V. H. Kraybill, R. E. Young*, Public Service Company of Northern Illinois; *M. Fisher, Jr.*, University of Illinois

Spotweld Monitoring by Resistance Change. *Herbert D. VanSciver*, Budd Company

Electronic Control for Monitoring the Resistance Change During a Spotweld. *S. S. Barnhart, W. B. Hills*, General Electric Company

Thursday, April 17

9:00 a.m. Power Supply for Resistance Welding Machines

Chairman: M. Zucker, Myron Zucker Engineering Company

Session Secretary: D. W. Nethercut

Opening Remarks. Prof. I. B. Baccus, Chairman, AIEE Michigan Section, Michigan State College

Introductory Remarks. E. L. Bailey, Chrysler Motor Company

Resistance Welding Machines—Their Ratings and Characteristics of Their Load. *W. G. Bostwick*, Precision Welder and Machinery Company

The Power Company's Viewpoint. *H. W. Tietze*, Public Service Electric and Gas Company of New Jersey

Synopsis of Users Section—Information for Power Users. *W. K. Boice*, General Electric Company

Typical Installations. *C. E. Pflug*, Nash Kelvinator Corporation

2:00 p.m. Resistance Welding

Chairman: J. F. Deffenbaugh, Federal Machine and Welder Company

Session Secretary: C. R. Molenaar

Up and Down Slope in Soot Welding. *I. W. Johnson*, General Electric Company

A New 3-Phase Welding System for Welding of Aluminum. *H. W. VanNess*, *E. C. Hartwig*, Westinghouse Electric Corporation

A New Method of Controlling Platen-Displacement vs. Time During Flash Welding. *Prof. E. E. Moyer*, *W. F. Savage*, Rensselaer Polytechnic Institute

Problems and Equipment in Aircraft Spot Welding. *J. R. Fullerton*, Ryan Aeronautical Corporation

5:30 to 10:00 p.m. Demonstration Session

Demonstrations of electric welding techniques and equipment, sponsored by Detroit Section of the American Welding Society

Friday, April 18

9:00 a.m. Fundamental Arc Research

Chairman: J. Heuschkel, Westinghouse Electric Company

Session Secretary: Prof. R. J. Krieger

Opening Remarks. V. H. Chisholm, Hudson Motor Company, President of IEESD

Characteristics of the Tungsten Arc in Argon-Helium Mixtures. *Prof. T. B. Jones*, *Merrill Skolink*, The Johns Hopkins University

Forces of Electromagnetic Origin in the Welding Arc. *William J. Greene*, Air Reduction Sales Company

High Speed Photography—A Technique for Arc Research. *Prof. R. J. Krieger*, Ohio State University

Some New Instruments to Aid in the Study of Welding Arc. *L. P. Winsor*, Rensselaer Polytechnic Institute

2:00 p.m. Arc Welding

Chairman: A. U. Welch, General Electric Company

Session Secretary: A. E. Johnson

Oscillographic Studies of the Shielded Inert Gas Metal Arc Welding Process. *R. W. Tuthill*, General Electric Company

Arc Welding Process for Making Electric Connections Between Small Aluminum Wires. *C. R. Dixon*, *Paul Dickerson*, Aluminum Company of America

Qualitative Instrumentation for D-C Arc Welding. *E. H. Wilhelm*, United States Naval Engineering Experiment Station

Design and Operating Characteristics of the Rectifier-Type Arc Welder. *H. J. Bichsel*, *E. Steinert*, Westinghouse Electric Corporation

5:30 to 8:00 p.m. Demonstration Session

Demonstration of electric welding techniques and equipment. Dr. A. DiGuilio, Consulting Chemical and Metallurgical Engineer, demonstration committee chairman

8:00 p.m. General Meeting With the Detroit Section of AWS

Chairman: E. J. Limpel, A. O. Smith Corporation

Session Secretary: L. C. Poole

Instrumentation From the Viewpoint of the User. *Walther Richter*, Consulting Engineer

9:00 to 10:00 p.m. Demonstration Session continued

Comprehensive Program Scheduled for AIEE North Eastern District Meeting

Two subjects of absorbing interest to residents of New York State and the New England states, hydroelectric developments on the Niagara River, and the St. Lawrence River development, will be featured at the 1952 AIEE North Eastern District Meeting, to be held at the Arlington Hotel, Binghamton, N. Y., April 30–May 2. This area, which includes the triple cities of Binghamton, Johnson City, and Endicott, is one of the fastest growing industrial communities in the eastern part of the United States. The meeting also marks the 50th anniversary of the host Section, the AIEE Ithaca Section.

By presenting some 15 technical sessions, with three sessions scheduled concurrently, the program for the North Eastern District Meeting will cover all phases of electrical engineering, with particular emphasis on power transmission, and distribution. Of special interest should be the Thursday afternoon Symposium on the Engineering Aspects of the Hydroelectric Development on the Niagara River at Niagara Falls and the St. Lawrence River Development near Messina, N. Y. Prominent AIEE members from both the United States and Canada plan to present papers.

INSPECTION TRIPS

A schedule and brief description of the various trips are given in the following. Members are urged to make reservations for these trips immediately upon registering at Headquarters. Advance registration by mail on the cards furnished for these trips will provide some indication as to how many expect to attend.

Goudey Generating Station, Westover, N. Y. (Wednesday afternoon, April 30). This generating plant, located adjacent to Binghamton, is the largest plant on the New York State Electric and Gas System. Very recently a new 75,000-kw reheat turbine generator went into operation. This is known as number 8 unit in the station. The machine uses steam at 1,250 pounds with 1,000-degree initial temperature and 1,000-degree reheat. Some of the more novel features of the plant will be covered in a talk given by company engineers.

Endicott Johnson Corporation, Johnson City, N. Y. (Thursday morning, May 1). Endicott Johnson is one of the largest shoe manufacturers in the United States. The inspection trip will be devoted primarily to the types of drives as found in their rubber mill and in the actual manufacture of shoes. This trip will be concluded with lunch at the Endicott Johnson cafeteria.

Link Aviation Corporation, Binghamton (Thursday afternoon, May 1). This factory is the location of the manufacturer of the widely known Link trainer. The present-day trainer only remotely resembles the Link trainer as used during World War II, and those making the trip will have a chance to inspect portions of the assembly line where these trainers are manufactured and may also have an opportunity to "fly" one of the units.

Ozalid Division of General Aniline and Film Corporation, Johnson City (Friday morning, May 2). This factory, to which a large addition recently was made, contains one of the largest coating machines in the world for the manufacture of sensitized paper. The motors and control involved are very novel. The well-known Ozalid reproducing machine also is made at this factory and inspection of the assembly aisles of these devices will be made. Lunch in the cafeteria will be served at the end of this trip.

International Business Machines Corporation, Endicott (Friday afternoon, May 2). This company manufactures a large number of

The Link trainer assembly line at Link Aviation Corporation will be inspected during the North Eastern District Meeting

Tentative Technical Program

North Eastern District Meeting, Binghamton, N. Y., April 30-May 2

Wednesday, April 30

9:30 a.m. Distribution for Coming Power Loads and Economics

Chairman: E. K. Karcher, Niagara Mohawk Power Company

DP. Impact of Future Loads on Distribution Systems.** *F. S. Black, Electrical World* magazine

DP. Economical Wire Sizes.** *A. T. Green*, Niagara Mohawk Power Corporation

DP. Economical Combinations of Transformers and Secondaries Brought Up to Date.** *V. A. Rydbeck*, General Electric Company

DP. Distribution Performance as an Index to Economical Design.** *T. D. DeVore*, Niagara Mohawk Power Corporation

9:30 a.m. Power Stations and Equipment

Chairman: S. W. Zimmerman, Cornell University

DP. Relay Protection of a Double-Circuit-Winding Generator.** *N. Stadtfeld, Jr.*, Westinghouse Electric Corporation

DP. High Integrated Fault Duty Field Test on 69-Kv Circuit Breaker.** *P. L. Taylor*, Allis-Chalmers Manufacturing Company

DP. Engineering Features of 60,000/75,000-Kw Reheat Unit, Goudey Station, Binghamton.** *W. Greacen, III, J. R. Stover*, New York State Electric and Gas Corporation

9:30 a.m. Electronics and Servomechanisms

Chairman: W. E. Meserve, Cornell University

52-120—ACO.* A New Partner for Electronic Control Systems. *R. L. Scrafford*, Cornell Aeronautical Laboratory

DP. Electronic Instruments for the Production Testing of Camera Shutters.** *R. Lavendar*, Ansco, Division of General Aniline and Film Corporation

DP. A Millimicrosecond Oscilloscope.** *L. G. Abraham, Jr.*, Graduate Student, Cornell University

52-121—ACO.* Piecewise Linear Servomechanisms. *J. W. Schwartz*, Graduate Student, Cornell University

2:00 p.m. Adequacy and Quality of Service

Chairman: A. E. Knowlton, *Electrical World* magazine

DP. Distribution Design for High-Density Loading.** *J. S. Williams*, Westinghouse Electric Corporation

DP. Standard Substation Design.** *L. F. McGowan R. W. Blake*, New York State Electric and Gas Corporation

DP. Functional Utilization of Aerial Cable.** *J. C. Hlavac*, Central Hudson Gas and Electric Corporation

DP. Merits of Bus and Feeder Regulation.** *W. L. Peterson*, Allis-Chalmers Manufacturing Company

DP. Capacitor Application.** *A. D. Tuttle*, New York State Electric and Gas Corporation

DP. Distribution Transformer Capabilities.** *J. B. Hodtum*, Allis-Chalmers Manufacturing Company

2:00 p.m Computing Devices

Chairman: J. W. Forrester

DP. Proof of Accuracy in Number Transmission as Applied to Computers.** *G. V. Hawkins*, International Business Machines Corporation

DP. A New Approach to Ring and Storage Circuits Without Triggers.** *E. S. Hughes, Jr.*, International Business Machines Corporation

DP. Control Problems to Be Solved on the Analogue Computer.** *A. O. Fitzner*, Westinghouse Electric Corporation

DP. Development of the Wire-Contact Relay.** *R. E. Markle*, International Business Machines Corporation

52-118. A Dial-Reading Translator for Digital Machine Inputs. *A. L. Klein, K. P. Gow*, Southern California Co-operative Wind Tunnel

2:00 p.m. Industrial Applications and Lighting

Chairman: R. O. Bell, Allis-Chalmers Manufacturing Company

DP. Distribution at 270/480 Volts for Power and Lights in Industrial Plants and Office Buildings.** *D. S. Brereton*, General Electric Company

DP. Low-Voltage Distribution Systems for Industrial Plants.** *H. L. McGee*, Westinghouse Electric Corporation

DP. Engineering Experience in the Application of Superimposed Frequencies for Clock Systems.** *W. Webb*, International Business Machines Corporation

DP. Features of Power Distribution in Westinghouse Electronic Tube Plants.** *F. J. Miller*, Westinghouse Electric Corporation

52-119. Lighting a Network Analyzer Area. *V. L. Dzwonczyk*, American Gas and Electric Service Corporation

2:00 p.m. Applications of Electricity in Aviation

Chairman: A. Montgomery

DP. Special Purpose Servo Analogue Computer for Aircraft Control.** *R. E. Frazier*, Cornell Aeronautical Laboratory

DP. The Modern Flight Simulator.** *W. W. Wood, Jr.*, Link Aviation, Inc.

DP. Practical Aspects of Servomechanism Amplifier Design.** *R. R. Redemske*, Servomechanisms, Inc.

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DP. Development of Potentiometers.** *L. Packard*, Technology Instrument Corporation

DP. The Comparative Advantages of Some Vector Analogues.** *C. D. Bock*, Arma Corporation

Thursday, May 1

9:30 a.m. Protection and Transformer Loading

Chairman: S. O. Schamberger, Niagara Mohawk Power Corporation

DP. Standard Fuse Links.** *W. L. Vest*, Western Massachusetts Electric Corporation

DP. Lightning Protection for Transmission Lines.** *R. M. Butler*, General Electric Company

DP. Latest Trends in Transformer Insulation.** *W. C. Seeley*, Allis-Chalmers Manufacturing Company

DP. Practice in Transformer Loading.** *A. F. Sedgwick*, United Illuminating Company

DP. Thermal Overload Indication on Power Transformers.** *J. F. Brubaker, E. A. Thompson*, Westinghouse Electric Corporation

9:30 a.m. Industrial Applications

Chairman: E. M. Guyer

DP. Industrial Applications of the Magnetic Amplifier.** *R. W. Moore*, Westinghouse Electric Corporation

DP. Economic Factors That Influence Dieselization and Electrification of Railways.** *C. Kerr*, Westinghouse Electric Corporation

DP. D-C Drive for Multisectional Machines.** *L. F. Lewis*, General Electric Company

52-122. Self-Excitation of Capacitor Motors. *G. Angst*, General Electric Company

9:30 a.m. Network Theory

Chairman: A. B. Credle, Cornell University

52-123. Semifinite Terminated Electric Wave Filters. *S. S. L. Chang*, Robbins and Myers, Inc.

52-124. The Effective Feedback Ratio of Magnetic Amplifiers. *L. A. Finzi, H. L. Durand, G. F. Pitman, Jr.*, Carnegie Institute of Technology. Presentation by title only for discussion'

52-125. A Turns Index for Pulse Transformer Design. *H. W. Lord*, General Electric Company

DP. Dieletric Amplifiers.** *G. W. Penney*, Carnegie Institute of Technology.

9:30 a.m. General Power

Chairman: I. B. Johnson

DP. Travelling Waves on Transmission Lines.** *E. W. Boehne*, Massachusetts Institute of Technology

DP. Apparatus Economy of Open-Delta Transformer Banks.** *J. E. Mulligan*, Worcester Polytechnic Institute

52-128. Capacitance and Surface Voltage Gradient of Transmission Lines. *H. B. Dwight, F. E. Scheidler*, Massachusetts Institute of Technology

DP. The Variation at Constant Density of the Dielectric Breakdown of Paper With Air Resistance.** *P. Cloke, K. K. Khandelwal*, University of Maine

2:00 p.m. Symposium—Engineering Aspects of Proposed Hydroelectric Developments in New York State and Ontario

Chairman: J. G. Tarboux, Cornell University, Vice-President, North Eastern District

DP. Proposed Increased Use of Hydroelectric Power on the American Side of the Niagara River.**

*** ACO:** Advance copies only available; not intended for publication in *Transactions*.

**** DP:** District paper; no advance copies are available; not intended for publication in *Transactions*.

E. S. Bundy, Vice-President and Chief Engineer, Niagara-Mohawk Power Corporation

DP. Generation and Transmission of Power From the St. Lawrence River.** *F. J. Leerburger*, Consultant to the New York State Power Authority

DP. Generation and Use of Niagara and St. Lawrence Power in Ontario.** *R. L. Hearn*, General Manager and Chief Engineer, The Hydro-Electric Power Commission of Ontario, Toronto

Friday, May 2

9:30 a.m. Distribution Maintenance

Chairman: George Fiedler, Rochester Gas and Electric Company

DP. Some Aspects of Joint Pole Use With Increasing Line Voltages.** *W. Bloeker*, American Telephone and Telegraph Company; *W. R. Ballard*, Ebasco Services, Inc.

DP. Chemical Treatment of Right of Way.** *L. Phillips*, Pennsylvania Power and Light Company

DP. Hot-Line Operations and Maintenance.** *R. M. Grogan*, Long Island Lighting Company

DP. Demonstration of Street Lighting Trouble Location.** *E. S. Licht*, New York State Electric and Gas Corporation

DP. What the Engineer Should Know About Wood Products.** *F. A. Ashbough*, West Pennsylvania Power Company

9:30 a.m. Conference on the Circuitry and Application of Transistors

Chairman: F. B. Bramhall, Western Union Telegraph Company

DP. Preview of Transistor Applications.** *R. A. York*, General Electric Company

DP. Application of Transistors in an Intermediate-Frequency Amplifier.** *D. M. Powers*, Raytheon Manufacturing Company

DP. Transistors in Pulse Circuits.** *A. E. Anderson*, Bell Telephone Laboratories, Inc.

9:30 a.m. Basic Science

Chairman: M. G. Malti, Cornell University

52-129. The Derivation of Vector Potential From Tables of Scalar Potential. *J. J. Smith*, General Electric Company

DP. A Study of the Electrical Behavior of Gases at High Pressure.** *Alexander Kusko*, Massachusetts Institute of Technology

DP. Analysis of Network Response to Periodic Waves.** *P. M. Seal*, University of Maine

52-126—ACO.* Tensor Analysis of Unbalanced 3-Phase Circuits. *Y. H. Ku*, Massachusetts Institute of Technology

9:30 a.m. Student Paper Contest

Chairman: W. H. Erickson, Cornell University

12:00 noon. Student Branch Chairmen and Counselors Luncheon, Arlington Hotel

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the IBM business machines in Endicott. It is one of the most modern industrial plants to be found in the United States. A guided tour through the factory will be of much interest to all electrical engineers, especially those interested in electronics.

All of the foregoing trips may be subject to change depending on security measures that could be imposed by the government. Busses will be available for transportation.

LADIES' ENTERTAINMENT

The Ladies' Entertainment Committee, under the chairmanship of Mrs. E. G. Kniffen, has arranged an interesting program.

On Wednesday, April 30, from 3:00 to 5:00 p.m., a get-acquainted tea will be held at the Arlington Hotel. At 6:30 p.m., a dinner and entertainment will be held at the Trinity Parish House. At 10:00 a.m. on Thursday, an inspection trip has been planned through the Kroehler Manufacturing Plant for home furniture. It will be followed by luncheon at the Binghamton Country Club and a bus sight-seeing trip to various points of interest in the area. On Thursday evening the ladies will join the men in the banquet to be held at the Arlington Hotel. On Friday at 10:00 a.m., coffee will be served at the hotel, followed by an inspection trip through the Sheltered Work Shop, a shop where physically handicapped people are gainfully employed. The remaining time will be available for shopping.

ENTERTAINMENT

The first event on the entertainment program will be the smoker to be held in the main ballroom of the Arlington Hotel on April 30. A lively evening is planned with M. M. "Irish" Kennealy as master of ceremonies. On Thursday evening, May 1, the main ballroom will be the scene of an informal banquet and social hour to which the ladies are cordially invited. Dexter Kimball, Professor Emeritus and former Dean of the College of Engineering, Cornell University, will act as toastmaster. He will give a résumé of the history of the activities of the AIEE Ithaca Section during the past 50 years. AIEE past president James F. Fairman, Defense Electric Power Administrator, will speak on "The Engineers' Role in Defense Mobilization."

Tables will be arranged for the smoker and banquet in groups of ten and all tables will be numbered. Reservations may be obtained from J. R. Stover, New York State Electric and Gas Corporation, 62 Henry Street, Binghamton, N. Y.

SPORTS

Golf has been planned for registered members and guests at the Binghamton Country Club. Arrangements may be made through any member of the Entertainment Committee or at the registration desk. No golf tournament has been scheduled, but members and guests may arrange for golf at their convenience.

HOTEL RESERVATIONS

Members planning to attend the North Eastern District Meeting are urged to make hotel reservations now to be sure of accommodations. The committee states that it will be necessary, where possible, to double up in rooms and that reservations may be made that way. Blocks of rooms have been reserved in the Arlington Hotel. However, late-comers may be required to take rooms in near-by hotels and motels. Reservations must be made before April 1 and requests should be sent directly to the hotel.

ADVANCE REGISTRATION

Advance registration by returning the advance registration card properly filled out, is requested. The registration fee, payable at the meeting, will be $2 for members and $3 for nonmembers. No fee will be required of enrolled sudents and immediate families of members. Registration begins at 8:30 a.m. on Wednesday, April 30, in the lobby of the headquarters hotel.

COMMITTEES

The following committees have been set up to facilitate plans for the 1952 North Eastern District Meeting:

General Advisory Committee. W. W. Perry (*General Chairman*), J. G. Tarboux (*Vice-Chairman*), E. B. Alexander (*Secretary*), R. F. Bovier, G. E. Dana, E. M. Guyer, M. S. Hall, K. S. Koon, J. P. Peterson, E. F. Wood, S. W. Zimmerman

Budget and Finance. L. F. McGowan (*Chairman*), R. W. Blake, W. J. Rider, S. Q. Stephens

Technical Program. M. S. McIlroy (*Chairman*), H. L. Livingood (*Vice-Chairman*), W. W. Wood

Hotel Reservations and Registration. A. O. Kenyon (*Chairman*), D. Dawson, R. E. Markle, A. Montgomery, E. Presley, H. W. Thomas, A. D. Tuttle, W. Webb

Publicity. N. L. Platt (*Chairman*), D. Purdy, L. H. Stantz, L. V. Vacca

Student Branch Activity. W. H. Erickson (*Chairman*), P. D. Ankrum, A. B. Credle

50th Anniversary Banquet and Smoker. J. R. Stover (*Chairman*), R. F. Bovier, P. P. Brereton, T. S. Cowen, A. G. Cox, L. A. Dudley, W. R. Jones, K. E. Personius, J. L. Scott

Inspection Trips and Transportation. J. P. Peterson (*Chairman*), A. Boon, A. R. Leinbach, R. New

Ladies Entertainment. J. E. Gahagan (*Chairman*), Mrs. Earl Kniflen (*Chairman, Ladies' Activities*), Mrs. E. Alexander, Mrs. L. Livingood, Mrs. J. Tarboux, Mrs. J. Wagner

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Progress in Quality Electronic Components to Be Subject of Conference, May 5-7

A conference on Progress in Quality Electronic Components will be held on May 5, 6, and 7 in Washington, D. C., at the Department of Interior auditorium, with Roger Smith Hotel as headquarters. In the sponsorship of this conference, the AIEE is joined by the Institute of Radio Engineers and the Radio-Television Manufacturers Association, with the active participation of several agencies of the United States Department of Defense and the National Bureau of Standards.

This conference is a sequel to a meeting sponsored by the same groups which attracted over 800 registrants to Washington in 1950. The program will include a review of the status of the electronics industry, particularly with regard to requirements of

Tentative Technical Program

Progress in Quality Electronic Components, Washington, D. C., May 5-7, 1952

Monday, May 5

10:00 a.m. Welcome

J. G. Reid, Jr., Chairman, Symposium Committee, National Bureau of Standards, Washington, D. C.

Session 1. Electronics Today

Chairman: A. V. Astin, National Bureau of Standards, Washington, D. C.

Electronic Production Requirements From Industry's Viewpoint. *Glen McDaniel*, President, Radio-Television Manufacturers Association

Electronics in the Defense Production Program. *J. A. Milling*, Chairman, Electronics Production Board, Defense Production Administration

Some Factors in Today's Electronics Production. *Capt. Rawson Bennett*, United States Navy, Bureau of Ships, Department of the Navy

Reliability of Military Electronics. *Edwin A. Speakman*, Vice-Chairman, Research and Development Board, Department of Defense

Electronic Components in Continental Europe. *Lt. Col. C. B. Lindstrand*, United States Air Force, Electronics Production Resources Agency, Department of Defense

Electronic Components in Great Britain. *W. A. G. Dummer*, Telecommunications Research Establishment, London, England

Electronic Components in Soviet Russia. *Maj. G. W. King*, United States Air Force, Air Technical Information Center, Wright-Patterson Air Force Base

2:00 p.m. Session 2. Basic Materials

Chairman: John N. Koenig, Rutgers University

Recent Developments in Ceramic Dielectrics. *Edward J. Smoke*, Rutgers University

Metallic Refractories, New Materials for the Electrical Industry. *Robert Steinitz*, American Electro Metal Corporation

Some Fluorochemicals for Electrical Applications. *N. M. Bashara*, Minnesota Mining and Manufacturing Company

Manufacture of Mica Paper for Insulation. *R. L. Griffeth, E. R. Younglove*, Mica Insulator Company

Progress in the Use of Teflon, Including Soldering and Cementing. *M. A. Rudner*, U. S. Gasket Company

Session 2B. Advances in Miniaturization

Chairman: Cledo Brunetti, Stanford Research Institute

Compact Assembly Methods. *S. T. Danko*, Signal Corps Engineering Laboratories, Fort Monmouth, N. J.

Reproducibility of Printed Components. *W. H. Hannahs, J. Eng*, Sylvania Electric Products, Inc.

Miniaturized Components for Transistor Application. *P. S. Darnell*, Bell Telephone Laboratories, Inc.

Tuesday, May 6

9:30 a.m. Session 3A. Progress in Basic Components

Chairman: Ernest Weber, Polytechnic Institute of Brooklyn

Adhesive Tape Resistors. *B. L. Davis*, National Bureau of Standards

Metallic Film Resistors. *C. T. Graham*, Polytechnic Research and Development Company

E-C Glass Resistors. *J. K. Davis*, Corning Glass Works

Stability of Standard Component Resistors. *C. K. Hooper*, Westinghouse Electric Corporation

Progress in the Field of Resistors. *Jesse Marsten*, International Resistance Company

Session 3B. Capacitors and Inductors

Chairman: R. C. Sprague, Sprague Electric Company

Capacitors for High Temperature Operation. *John W. Schell*, Erie Resistor Corporation

Expected Performance of Glass Capacitors. *Gail Smith*, Corning Glass Works

Tantalytic Capacitors. *L. W. Foster*, General Electric Company

Progress in Size and Performance of Transformers. *G. E. Wilson*, General Electric Company

Ferrite Inductor Cores. *W. W. Stifler, Jr.*, Ferroxcube Corporation of America

2:00 p.m. Session 4A. Miscellaneous Components

Chairman: John H. Miller, Weston Electrical Instrument Corporation

Selection of Fuse Protection for Electronic Circuits. *E. V. Sundt*, Littelfuse Inc.

Design Factors Influencing the Reliability of Relays. *J. R. Fry*, Bell Telephone Laboratories, Inc.

Vibrators for the Armed Services. *K. M. Schafer*, P. R. Mallory and Company, Inc.

Indicating Instruments for Use Under Severe Conditions. *F. X. Lamb*, Weston Electrical Instrument Corporation

Influence of Wire and Cable on Improved Components. *F. M. Oberlander*, Radio Corporation of America

Teflon Wire. *C. E. Dodge, Jr.*, Warren Wire Company

Session 4B. Design and Production Methods

Chairman: M. R. Briggs, Westinghouse Electric Corporation

Unitized Packaging by the Laminar Method. *G. Heitert*, Emerson Electric Manufacturing Company

Heat Transfer From Electronic Components. *Walter Robinson*, Ohio State University Research Foundation

Packaging Principles Employing Plastics and Printed Wiring to Improve Reliability. *W. J. Clarke, N. J. Eich*, Bell Telephone Laboratories, Inc.

8:00 p.m. Session 5. An Evening With Transistors

Chairman: J. A. Morton, Bell Telephone Laboratories, Inc.

The Transistor Development Status at Bell Telephone Laboratories, with demonstration. *W. R. Sittner*, Bell Telephone Laboratories, Inc.

Transistor Power Amplifiers, with demonstration. *R. F. Shea*, General Electric Company

Availability of Transistors. *Lt. Col. W. F. Starr*, United States Air Force, Electronics Production Resources Agency, Department of Defense

Wednesday, May 7

9:30 a.m. Session 6A. Aspects of Reliability

Chairman: J. A. Chambers, Motorola, Inc.

Electronic Failure Prediction. *James H. Muncy*, National Bureau of Standards

Part Failure Problem in Navy Electronics Equipment. *M. M. Tall*, Vitro Corporation of America

How Can the Reliability of Electronic Systems Be Improved Now? *W. Wagenseil*, Hughes Aircraft Company

Component Part Specifications. *D. E. Brown*, Vitro Corporation of America

A Component Manufacturer Looks at Reliability. *Leon Podolsky*, Sprague Electric Company

Session 6B. Electron Tubes

Chairman: Charles R. Banks, Aeronautical Radio, Inc.

Sealed-in-Glass Germanium Diodes. *J. W. Dawson*, Sylvania Electric Products, Inc.

Reliability of Premium Subminiature Tubes. *P. T. Weeks*, Raytheon Manufacturing Company

Methods for Achieving Maximum Reliability in Vacuum Tube Applications. *R. L. Kelly*, Radio Corporation of America Tube Department

Failure of Vacuum Tubes From Interface Formation. *W. H. Kliever*, Minneapolis-Honeywell Regulator Company

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the present defense program. New materials, components, and production techniques for electronics will be included as well as attainment of improved reliability in electronic equipments.

Outstanding members of the electronics field will contribute 46 papers to the 3-day program. An evening session, including demonstrations of transistors, is scheduled.

Registration will be at the Roger Smith Hotel beginning at 9:00 a.m., May 5, and continuing each day of the conference. Fees will be $2.50 in advance and $3.50 at the time of the conference.

Tentative Schedule Indicates Subjects of Summer General Meeting Sessions

A preview of the technical program for the 1952 Summer General Meeting of the AIEE, to be held at the Nicollet Hotel, Minneapolis, Minn., June 23–27, indicates a variety of technical sessions and conferences on subjects ranging from the chemical industry to computing devices and rotating machinery. In addition, the Annual Meeting of the Institute will be held on Monday morning, June 23, at which the new AIEE President-elect will be introduced. A tentative schedule of the sessions as currently planned for the five days of the meeting is as follows:

Monday, June 23

Transmission and Distribution
Electronic Power Converters
Computing Devices
Industrial Control

Tuesday, June 24

Section Policy
Transformers
Wire Communication Systems
Transmission and Distribution
Instruments and Measurements
Sections Delegates Conference
Communication Switching Systems

Wednesday, June 25

Safety
Rotating Machinery
Insulated Conductors
Basic Sciences
Feedback Control Systems
District Branch Prize Papers
Management
Industrial Power Systems
Chemidal Industry

Thursday, June 26

Rotating Machinery
System Engineering
Electromedical Problems
Magnetic Amplifiers
Chemical Industry
Carrier Current
X-Ray Radiation
Dielectrics

Friday, June 27

Power Generation
Relays
Electronics
Land Transportation
Switchgear
Selenium and Tellurium
Mining and Metal Industry

INSPECTION TRIPS

Inspection trips have been arranged to the University of Minnesota, the Northwestern Bell Telephone Company, Northwest Airlines' maintenance center, steam and hydroelectric plants of the Northern States Power Company, the *KSTP* Television Station, and manufacturing facilities of General Mills, of Electric Machinery and Manufacturing Company, and Minnesota Mining and Manufacturing Company. There also will be a sight-seeing tour of Minneapolis and St. Paul.

Trips to the University of Minnesota will include a visit to the engineering buildings, where a linear accelerator is under construction and where a computing center has been set up featuring the Reeves Analogue Computer. A trip through the hydraulics laboratory, located near St. Anthony's Falls in the Mississippi River, has been scheduled. A third trip will be to the Rosemount Research Laboratory, the large aeronautical research center operated by the university.

Of interest to communications engineers will be the new terminal equipment for several major types of toll cable, to be seen at the Northwestern Bell Telephone Company's building. Facilities for toll dialing and for the television network connections are also in this building.

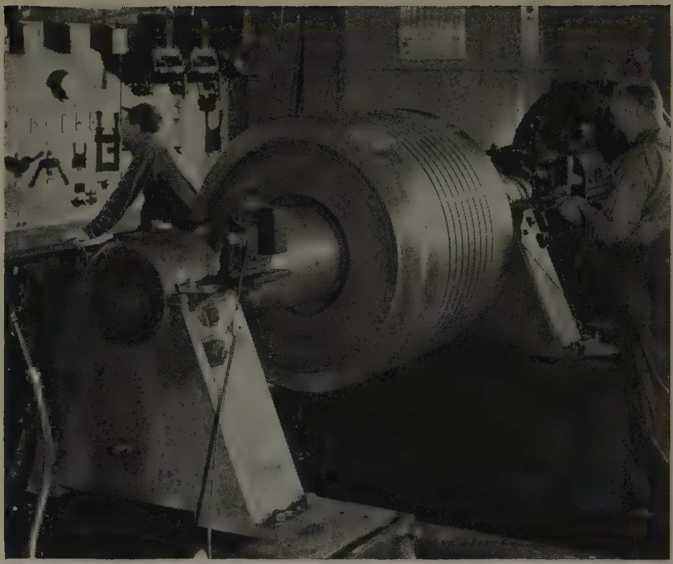
The Riverside Steam Plant of the Northern States Power Company is the largest single source of generation on this company's system. This plant, located along the Mississippi River in Minneapolis, will be open for a visit by those attending the Summer General Meeting. An all-day trip has been arranged to Holcombe, Wis., in order to inspect the Northern States Power Company's hydroelectric installation there.

No industrial inspection of the "Twin Cities" would be complete without a visit to some of the Minneapolis grain processing plants. In the trip to General Mills, visitors will tour one of Minneapolis' largest flour mill groups and a model mill and laboratory. Modern sectionalized electric mill drives can be inspected, and compared with old water-wheel drives and a large steam-engine drive which have been retained.

At the Electric Machinery and Manufacturing Company factory, construction of large units of rotating machinery may be observed. This trip also features allied control equipment and magnetic variable speed drives.

The Minnesota Mining and Manufacturing Company, in St. Paul, is well known for its "Scotch" tapes. Visitors to its plant can observe the production of high grade electric tape and a demonstration of this company's magnetic sound recording tape.

Shown at the Electric Machinery Manufacturing Company, one of the inspection trips during the Summer General Meeting, is a balancing rotor for one of eight 3,000-horsepower 1,800-rpm 4,160-volt 3-phase 60-cycle motors for driving petroleum pipe line pumps. These pumps are believed to be the largest of this type ever built for this service



SOCIAL PROGRAM

In addition to social events in the evenings, something of interest for the ladies is provided each day of the meeting. On Monday afternoon they will meet for tea at the Campus Club, following a tour of the campus of the University of Minnesota. A trip by bus toward the Lake Minnetonka region is planned for Tuesday morning. Gardens will be visited enroute, followed by a luncheon at the Minneapolis Automobile Club, along the Minnesota River.

On Wednesday a breakfast and fashion show at Donaldson's department store will precede a visit to the Red Wing Potteries. These will be reached by a scenic bus trip along the Mississippi River. The Betty Crocker Kitchen of General Mills will be visited Thursday morning. In the afternoon a tea in Scandanavian surroundings will be held at the Swedish Art Institute, followed by a tour of the building.

Arrangements will be made to accommodate golfers, fishermen, and sight-seers. Swimming, canoeing, and boat rides are available, under municipal control, on some of the lakes in Minneapolis. The dinner-dance Thursday evening will be the high spot of the social program.

TRANSPORTATION AND RESERVATIONS

Minneapolis is served by six air lines, nine railroads, and five longhaul bus lines. Double-decked stratocruisers, the largest airplanes in domestic service, operate between Minneapolis and New York, Washington, Chicago, Seattle, and intermediate cities. Between the Twin Cities and Chicago there are 20 trains each way, including the fastest in the world. Some of these run alongside the Mississippi River for as much as 300 miles and feature observation domes for viewing the scenery. Service to and from the West Coast is provided by seven daily trains each way, and a dozen more come from Houston, Denver, St. Louis, or Kansas City.

Those who plan to drive may obtain information and maps by writing the Tourist Information Bureau, Minneapolis Chamber of Commerce, 1750 Hennepin Avenue, Minneapolis 3, Minn.

Room reservations may be made by writing directly to the Nicollet Hotel, Minneapolis, or to the hotel of your choice, and stating that the reservation is for the AIEE Summer General Meeting.

Rooms with bath are available at the following rates:

Hotel	Single	Double	Twin Beds
Nicollet	$5.00–10.00	$7.50–12.50	$7.50–12.50
Andrews	3.75– 6.00	5.25– 7.50	6.50– 9.00
Dyckman	3.25– 6.00	5.50– 8.50	6.00–11.25
Sheridan	3.25– 3.50	4.50– 6.00	7.00– 8.00
Curtis	3.50– 5.00	4.50– 6.00	6.50– 7.50
Leamington	4.50– 5.50	6.00– 7.50	7.50– 9.50

AIEE Board of Directors Holds Meeting at Institute Headquarters

A regular meeting of the AIEE Board of Directors was held at Institute headquarters, New York, N. Y., on January 24, 1952.

The minutes of the meeting of the Board of Directors held in Cleveland, Ohio, on October 25, 1951, were approved.

Actions of the Executive Committee on membership applications as of November 23 and December 28, 1951, were reported and confirmed, as follows: November 23—41 applicants transferred to the grade of Fellow; 92 applicants transferred and 9 elected to the grade of Member; 142 applicants elected and 1 reinstated to the grade of Associate Member; 12 applicants elected to the grade of Affiliate; 845 Student members enrolled. December 28—5 applicants transferred to the grade of Fellow; 25 applicants transferred and 7 elected to the grade of Member; 202 applicants elected and 1 reinstated to the grade of Associate Member; 10 applicants elected to the grade of Affiliate; 494 Student members enrolled.

Recommendations adopted by the Board of Examiners at meetings held on November 15, and December 20, 1951, and January 17, 1952, were reported; and, upon recommendation of the Board of Examiners, the following actions were taken: 3 applicants were transferred to the Fellow grade; 29 applicants were transferred and 2 were elected to the Member grade; 149 applicants were elected to the Associate Member grade; 17 applicants were elected to the Affiliate grade; 161 Student members were enrolled.

The abbreviation "Affil. AIEE" was adopted for the new Affiliate grade.

The Directors accepted recommendations of the Board of Examiners that when a former member indicates that he wishes to reaffiliate himself with the AIEE and selects re-election, he cannot later change to the reinstatement procedure, and that a limitation be placed on the period a person can allow membership to lapse and request reinstatement; if the lapse has been for a longer period, re-election alone is permissible.

A proposal was submitted by the Board of Examiners for the transfer of F. L. Lawton, of Montreal, Quebec, Canada, to the grade of Fellow—the first proposal for the Fellow grade under the new constitutional requirements for that grade. The Board of Directors voted to invite Mr. Lawton to become a Fellow of the Institute.

FINANCES

Chairman Barrett of the Finance Committee reported disbursements from general funds, as follows: November 1951, $88,220.57; December 1951, $71,264.83; January 1952, $83,407.97.

Mr. Barrett reported repayment of the loan of $300 for the Machine Tool Conference, held in November 1951, made in advance of the conference, and stated that advances have been made to two other conferences: Joint AIEE-Institute of Radio Engineers Computer Conference, Philadelphia, Pa., December 1951, $200; Electronic Instrumentation in Nucleonics and Medicine, New York, N. Y., January 1952, $400.

A report of income and expenditures during the expired portion of the present budget year indicated receipt of approximately 20 per cent of the anticipated income of $960,000, and expenditures of 34.8 per cent of the budget of $966,000. These figures are quite comparable with corresponding figures at the same time last year.

The Board adopted a resolution to drop from membership any person owing dues for the fiscal year which began May 1, 1950, with the understanding that the suspended member may become reinstated without the formality of an application for reinstatement if dues in arrears are paid prior to May 1, 1952.

Upon recommendation of the Finance Committee, the Secretary was authorized to continue during the fiscal year beginning May 1, 1952, the exchange allowance to members in other countries which has been in effect for several years, involving payment of membership dues on the basis of the par currency value of countries affected by abnormal exchange rates; the member concerned being granted an exchange allowance corresponding to the difference between the New York exchange value and the normal par of his currency, such allowance not to exceed 40 per cent of the dues payable and not to apply to purchases of or subscriptions to Institute publications. A corresponding reduction in appropriation payments is applicable to Institute Sections in any countries affected.

RECOMMENDATIONS AND REPORTS

Upon recommendation of the Committee on Planning and Co-ordination, the Board authorized the following meetings:

District 2 Meeting, Charleston, W. Va., September 29–October 1, 1953
District 2 Meeting, Reading, Pa., October 5–7, 1954
District 1 Meeting, Rochester, N. Y., May 4–6, 1955

Chairman W. Scott Hill of the Professional Division Advisory Committee, present upon invitation, presented a report and recommendations concerning his committee, which was authorized on an experimental basis by the Board of Directors in April 1947, as a co-ordinating committee of a group of nine general committees of the Institute. Upon recommendation of the committee, based on the fact that no important activity or function has been required of the committee, the Board voted to discontinue the committee at the end of the present administrative year.

A plan for divisional operation of technical committees, prepared by Chairman M. D. Hooven of the Committee on Planning and Co-ordination as a committee of one appointed for this purpose, was submitted by Mr. Hooven, and was adopted by the Board of Directors in principle. The plan included the merger of the Technical Program Committee and the Technical Advisory Committee into one committee, named "Committee on Technical Operations," and described the composition and functions of that committee, the division committees, and the technical committees, and provisions for co-operation with general committees having specific interest in technical activities. It also formalized the forum of technical committee chairmen.

A report was presented of the Exploratory Group to Consider Increased Unity in the Engineering Profession, consisting of representatives of 15 engineering societies. The report included, for submission to the participating societies, a plan for the formation of a unity organization from the expansion and modification of Engineers Joint Council—in other words, an organization of engineering societies. This plan was not acceptable to the Board of Directors, and the Institute's representative on the Exploratory Group was requested to continue efforts to bring about a unity organization of individuals, which is the type of organization favored by a majority of AIEE members in a survey of membership opinion conducted by the Institute.

Chairman K. B. McEachron of the Publication Committee, present by invitation, presented recommendations of the committee for a series of three publications to take the place of the *Proceedings*, to be issued every two months on an annual subscription basis, as follows: Electronics and Communication (material in the Communication Division and the Science and Electronics Division), Applications and Industry (material in the General Applications Division and the Industry Division), and Power Apparatus and Systems (material in the Power Division)—the first two to be issued in the same month; Power Apparatus and Systems, the largest publication, to be issued in alternate months. The committee further recommended that, with the adoption of the plan for divisional publications, the *Transactions* be bound annually in three parts: Part 1, Electronics and Communication; Part 2, Applications and Industry; Part 3, Power Apparatus and Systems. The Board adopted the recommendations of the Publication Committee, effective in July 1952.

The following committee chairmen, present by invitation, discussed the activities of their committees: G. T. Minasian, Committee on Public Relations; Merwin Brandon, Technical Program Committee; W. R. Brownlee, Power Division Committee; E. I. Green, Science and Electronics Division Committee; Carl F. Scott, General Applications Division Committee.

The provision which was in force during the past two years for travel allowance for the Vice-President of the Canada District (10) to visit the Vancouver Section, now a part of the North West District (9), once each year, was continued for another period of two years. The object is to maintain contact in Canadian matters.

Upon recommendation of the Board of Examiners and Committee on Constitution and Bylaws, the Board approved, for submission to the membership for vote, amendments to the following sections of the Constitution of the Institute: Article II, Sections 4, 5, and 6; Article III, Section 11; Article XI, Sections 68, 69, and 70.

The Board received with regret the resignation of R. T. Henry as an AIEE representative on the following two organizations, because of his retirement from active service and change in location to southern California: (1) Standards Council, American Standards Association; (2) Engineering Societies Committee of the Thomas Alva Edison Foundation. The President was empowered to appoint his successor in each case, and the Secretary was requested to write a letter of appreciation to Mr. Henry for his long service on the Standards Council of ASA.

Upon petitions from the members concerned and recommendation of the Sections Committee, authorization was given for the establishment of two new Sections of the Institute: Tampa Section, from the former Tampa Subsection of the Florida Section; Delaware Bay Section, from the Wilmington Subsection of the Philadelphia Section, the latter effective June 1, 1952.

The following actions also were taken upon recommendation of the Sections Committee: A request of the Florida Section for a change in name to Jacksonville Section was granted; and the transfer of Madison, Tensas, Franklin, Caldwell, and Winn Parishes in Louisiana from the New Orleans Section in District 4 to the Shreveport Section in District 7 was approved, the object being to form a Subsection in the area of Monroe, La., under the sponsorship of the Shreveport Section.

The Student Branch of the Institute at

Harvard University was discontinued, upon the recommendation of the Committee on Student Branches, in view of the fact that emphasis at Harvard has been shifted to mechanical engineering to the almost complete exclusion of electrical and other engineering fields.

The Board adopted amendments to the following sections of the AIEE Bylaws, recommended by the Committee on Constitution and Bylaws, some of which implemented the action of the Board in adopting the recommended plan for divisional operation of technical committees: Sections 2, 16, 29, 35, 65, 83, 88, 90, 91, 98, 102, and 103.

Appointment by the President of the following representatives of the Institute on the National Engineers Committee of Engineers Joint Council was confirmed: Leo H. Cleary, Washington, D. C.; R. W. Sorensen, Pasadena, Calif.

The Byard referred to the President with power the appointment of AIEE representatives on:

Committee on International Relations, Engineers Joint Council

Engineering Manpower Commission, EJC

Joint AIEE-IRE Co-ordination Committee

Two delegates to the Annual Meeting of the American Academy of Political and Social Science

Three advisers to the Institute of International Education on the placing of foreign students in electrical engineering

The Board approved a resolution adopted by the Committee on Safety endorsing a new method of artificial respiration (*EE, Mar '52, p 283*).

ATTENDANCE

Present at the meeting were: *President* F. O. McMillan; *Past Presidents* J. F. Fairman, T. G. LeClair; *Vice-Presidents* H. R. Fritz, E. S. Lammers, Jr., N. M. Lovell, J. A. McDonald, F. W. Norris, J. R. North, C. S. Purnell, J. C. Strasbourger, J. G. Tarboux, W. R. Way; *Directors* W. J. Barrett, F. R. Benedict, R. F. Danner, E. W. Davis, D. D. Ewing, C. W. Fick, A. H. Frampton, N. B. Hinson, M. D. Hooven, Elgin B. Robertson, H. J. Scholz, Victor Siegfried; *Treasurer* W. I. Slichter; *Secretary* H. H. Henline.

Programs Announced for the AIEE Textile Conferences

The Annual Conference on Electrical Application for the Textile Industry, sponsored by the Textile Industry Subcommittee of AIEE, will be held, for the Northern group, at the Philadelphia Textile Institute, Philadelphia, Pa., on Thursday, April 24, 1952, and for the Southern group, at the Georgia Institute of Technology, Atlanta, Ga., on Thursday and Friday, May 1 and 2, 1952.

PHILADELPHIA PROGRAM

The program for the AIEE Textile Conference in Philadelphia is as follows:

High Accuracy Speed Measurement. *W. L. Russell*, E. I. du Pont de Nemours and Company

Stroboscopic Measurement in Textiles. *W. Saylor*, General Radio Corporation. Companion papers by Mr. Sepavich and others are planned

Vibration Control of High-Speed Spindles. *H. H. Wormser*, Universal Winding Company

Loom Desynchronizing. *F. D. Snyder*, Westinghouse Electric Corporation. Comments are to be prepared by G. Winterburn, Winterburn Associates

Tension Measurements in Spinning. *Ray Parker*

A tour of the Philadelphia Textile Institute will be held during the conference.

ATLANTA PROGRAM

Registration will be held at 9:00 a.m., Thursday, May 1, at the Georgia Institute of Technology Hightower Textile Building, with invitations being extended to all members of mill management and operation throughout the whole Southeast textile area to attend and bring as many guests as may be desired.

The Textile Industry Subcommittee has arranged a program of discussion and demonstration for this meeting that is intended to meet the problems confronting so many of the mills in the area. All papers will be limited to 30 minutes, with a 30-minute period open for discussion of each one.

The trends emphasized in the Thursday morning session are to the point with the latest development of high-speed machinery and the attendant increase in the hazards of vibration in mills. On Thursday afternoon the emphasis is on some of the most frequently occurring problems of what to do with electric equipment and maintenance in mills. With Friday morning's session the subjects are selected for their bearing on the planning stages of mill design and operation, and are intended to reduce the future problems of all of mill men who are in the textile business to stay.

May 1

10:00 a.m. Vibration

Some Effects of Vibration in Textile Mills. Liberty Mutual Insurance Company

Loom Desynchronizing. *Fred Snyder*, Westinghouse Electric Corporation

Vibration Control of High-Speed Spindles. Universal Winding Company

9:00 p.m. Maintenance and Utilization of Electric Equipment

Fundamental of Special Motor Applications in Textile Mills. Louis Allis Company

Maintenance of Electric Equipment in Textile Mills. *Dan McConnell*, Cone Mills Corporation

Discussion and decision on **Desired Characteristics of Enclosures for Sparking Parts in Textile Mills**

May 2

9:00 a.m. Wiring Problems in Textile Mills

Fundamental Insulation Requirements for Exterior and Interior Power Distribution Systems and Flexible Cords. Okonite Company

High-Voltage Distribution and Unit Substations as Applied to a Textile Mill. *Ben Swain*, Bibberstein and Bowles

The Application of Electric Equipment to Looms and Other Textile Machines. *V. F. Sepavich*, Crompton and Knowles Loom Works

Rectifying Devices to Be Subject of Conference in Pittsburgh

A special feature of the AIEE Conference on Electronic Converter Applications and Tubes, to be held May 19–20, 1952, at Pittsburgh, Pa., will be a panel discussion of the various types of rectifying devices now in use. The main purpose of this discussion, which will take place on Monday evening, May 19, is to review the present status of the various devices and to discuss the future possibilities of each.

The various types of rectifier units to be discussed are: "Ignitrons," by C. R. Marcum, Westinghouse Electric Corporation; "Excitrons," by H. Winograd, Allis-Chalmers Manufacturing Company; "Hot Cathode Tubes," by H. C. Steiner, General Electric Company; "Metallic Rectifiers," by I. R. Smith, Westinghouse Electric Corporation; "Mechanical Rectifiers," by O. Jensen, I-T-E Company; and "Glass Bulb Rectifiers and European Manufacture," by J. T. Thwaites, Canadian Westinghouse Company. The discussion of each type will cover engineering data regarding capabilities and characteristics of the basic device; a description of a typical unit showing its construction and distinctive features; an illustration of how a number of units may be combined to obtain desired higher ratings; and a discussion of development and application trends. The meeting then will be opened to questions and discussion from the floor.

This panel discussion will provide an excellent opportunity for anyone interested in these types of rectifiers to obtain information from both the manufacturers and users of the present commercial units.

Electric Heating Committee Holds Conference in Cleveland

The AIEE Cleveland Section was host to the Institute's first Induction and Dielectric Heating Conference at the Carter Hotel, Cleveland, Ohio, February 19–20, 1952. Approximately 350 members and guests registered for the program which included 13 technical papers and an open forum discussion with customer problems answered by a board of seven experts.

E. H. Lee of the Federal Communications Commission discussed interference problems with other communication services and new regulations, to become effective on July 1, covering certification of high-frequency heating equipment. Other speakers on the program were: H. G. Carlson, General Electric Company; J. W. Cable, Consulting Engineer; R. F. Snyder, Goodyear Tire and Rubber Company; R. C. Walter, Chevrolet Saginaw Transmission Division, General Motors Corporation; J. W. Williamson, Tocco Division, Ohio Crankshaft Company; H. E. Somes, H. E. Somes Engineering and Manufacturing Company; J. T. Sabol, Tocco Division, Ohio Crankshaft Company; H. F. Kincaid, International Harvester Corporation; W. H. Hickok, Thermex Division, The Girdler Corporation; M. P. Vore, Westinghouse Electric Corporation; B. E. McArthur, Magnethermic Corporation; F. T. Chesnut, Ajax Electrothermic Corporation; P. F. Good, Westinghouse Electric Corporation; H. C. Gillespie, Radio Corporation of America; W. C. Rudd, New Rochelle Tool Corporation; J. T. Vaughan, Tocco Division, Ohio Crankshaft Company; O. Weitmann, Lepel High-Frequency Laboratories; T. P. Kinn, Westinghouse Electric Corporation.

J. E. Eiselein, Radio Corporation of America, was general chairman of the conference. He was assisted by W. C. Rudd, J. T. Vaughan, T. P. Kinn, and C. J. Beller on program, publicity, and local arrangements, with the co-operation of R. S. Gardner at AIEE headquarters.

Plans are now underway to hold a similar conference in 1953. The Electric Heating Committee will be glad to receive suggestions on needed or available material for future programs of this type. Its activities cover all forms of electric heating for industrial applications, including furnaces, induction, dielectric, resistance, and radiation heating. Institute members and students interested in attending or contributing to the activities of this committee should write Harold Bunte, Secretary, AIEE Electric Heating Committee, Commonwealth Edison Company, 72 West Adams Street, Chicago 90, Ill.

Feedback Control Systems Provide Conference Subject

A Conference on Feedback Control Systems, sponsored by the AIEE Committee on Feedback Control Systems, was held at Atlantic City, N. J., December 6–7, 1951. The objectives of the conference were to recapitulate important developments in the field during the past few years and to present significant new developments. A total of 472 engineers, physicists, and mathematicians attended sessions at the Chalfonte-Haddon Hall Hotel.

Some of the papers presented considered theoretical concepts such as the application of statistical concepts to servomechanism design and the application of frequency response characteristics to the analysis of nonlinear and sample data control systems. Other papers were comprehensive reports on practical problems such as the design and use of precision potentiometers, electromatic resolvers, and electronic amplifiers for instrument servomechanisms. A significant contribution was the discussion of a combination digital and analogue automatic control system being designed for precision control of machine tools. One session was devoted entirely to the problems of control systems including human operators. It was also suggested that many animals have several characteristics which might well be used in analogous forms by mechanisms to improve their over-all performance.

The reception of the conference papers was most favorable. The interest in the nonlinear system of the human engineering aspects of feedback control and the marriage of analogue and digital systems are apparently of very basic interest at the present time. The Committee on Feedback Control Systems has decided to schedule conferences only when they can add greatly to the basic endeavor of sponsoring technical papers for the AIEE *Transactions*.

Transmission and Distribution Committee Holds Meeting

The AIEE Transmission and Distribution Committee (S. B. Crary, *Chairman;* F. V. Smith, *Vice-Chairman;* E. K. Huntington, *Secretary*), met on Tuesday, January 22, during the recent Winter General Meeting in New York, N. Y., for a discussion of activities and plans. This meeting was followed by five sessions, sponsored by the subcommittees, which give an indication of their activities.

The first session, conducted by the Distribution Subcommittee, dealt with operating data for distribution circuits and discussed the advantages and disadvantages for distribution voltages above 5,000 volts. The second session, sponsored by the Lightning and Insulators Subcommittee, consisted of four technical papers dealing with high-voltage, 60-cycle, and impulse characteristics of gaps and insulation, radio noise and corona, and insulation co-ordination of high-voltage lines and stations.

The Towers, Poles, and Conductors Subcommittee and the General Systems Subcommittee sponsored the third session which was a conference-type session during which representatives of six power companies presented their experience combating sleet on their transmission lines. This session, one of the first dealing with this subject, was very well attended. The fourth session, sponsored by the General Systems Subcommittee, presented a joint AIEE-Edison Electric Institute report on line outages for 236,666 mile-years of operating experience; another subcommittee paper dealt with the recovery voltage characteristics of distribution circuits to assist in formulation of performance requirements of protective devices, a joint study with the Protective Devices Committee. The fifth session dealt with stability problems and a study of incremental transmission-line losses to improve the economy loading of large interconnected systems.

An additional item was an interim report by the Capacitor Subcommittee dealing with guides for the short-time 60-cycle overvoltage operation of power capacitors and improvements in methods of calculating long-line performance. The committee is also planning an additional review of the sleet melting papers for the Summer General Meeting and additional work in regard to the design of transmission tower lines. This is of particular interest during this period in which many companies are considering higher voltage levels for both transmission and distribution systems.

Lehigh Valley Section Shows New Resuscitation Methods

On February 15, 1952, the AIEE Lehigh Valley (Pa.) Section inaugurated a program

Committee and speakers for the Feedback Control Systems Conference in Atlantic City, N. J., December 6–7, 1951, included (front row, left to right): Dr. R. J. Kochenburger, E. R. Behn, Dr. S. W. Herwald, Dr. G. S. Brown, R. Redemske, Professor O. H. Schmitt, Dr. C. Miller. Also (back row, left to right): Dr. J. R. Ragazzini, Arthur Cooper, A. L. Schumacker, H. T. Marcy, Dr. W. K. Linville, O. H. Shuck, W. M. Pease, R. S. Gardner, Albert Sciorra, J. Zauderer

of one meeting each year on the subject of safety by presenting a demonstration of the improved methods of artificial respiration. The demonstration was given by D. E. Albertson, Safety Engineer for the Pennsylvania Power and Light Company, at a dinner-meeting in Hazleton, Pa. Mr. Albertson pointed out that the Pennsylvania Power and Light Company was the first utility to adopt the new method, doing so on December 10, 1951. The speaker also stated that at the present time, the training of the company's personnel in the new method was 85 per cent complete and the cost has been entirely absorbed in the routine operation of the Safety Department.

The meeting was attended by some 140 Section members and guests who showed an active interest in the subject by asking questions and volunteering as victims for the demonstrator. The victims were all enthusiastic over the increased effectiveness of the new method. In addition to the back-pressure, arm-lift (Holger Nielsen) method, the back-pressure hip-lift and hip-roll methods were demonstrated. Mr. Albertson further pointed out that all of the so-called push-pull methods provide as much air to the lungs as the victim can take and, therefore, are as good as a mechanical resuscitator. (The push-pull method of artificial respiration was endorsed by the AIEE Committee on Safety at a meeting on January 23, 1952.)

A second portion of the program was an illustrated talk by Stanley C. Townsend, an electrical engineer with the Pennsylvania Power and Light Company. Mr. Townsend used 3-dimensional colored slides of various substations and power plants throughout the United States to show modern trends in engineering and construction.

Continuing its plan to acquaint prospective engineers with its activities, seven students from the Hazleton high schools were present as guests of the Section.

Long Distance Dialing Illustrated at Schenectady Section Meeting

More than 200 persons attended a joint meeting of the Schenectady Sections of the AIEE and the Institute of Radio Engineers on February 6, 1952. Feature of the evening was a lecture-demonstration given by M. S. Paige of the New York Telephone Company on "Dialing Far-Away Places" which proved educational and entertaining. Chairman for the meeting was A. W. Coolidge of the local AIEE Section.

Mr. Paige's discussion included comparisons through the years of the time it took to place a long distance call, and the cost of a typical 3-minute station-to-station call. He also discussed one of the most important developments in telephone history, "operating toll dialing," a method whereby a local operator may dial direct to a subscriber in a distant city. During the demonstration, a Bell Telephone operator, seated at a portable switchboard, placed the various long distance calls made by members of the audience. Loud-speakers in the Civic Playhouse in Schenectady, where the demonstration was held, enabled the audience to hear both ends of the long distance calls.

In an illustrative call, C. C. Herskind, Secretary of the local Section, talked with A. A. Johnson, Chairman of the AIEE Pittsburgh Section, to extend greetings and discuss plans of a forthcoming committee meeting. D. S. Brereton, a member of the Schenectady Section, spoke with Professor E. C. Crockett, who is Professor of Economics and Chairman of the Social Sciences Department at the University of Colorado at Boulder. The pros-and-cons of California weather made for a spirited conversation between Dr. Louis Rader, Schenectady Section Chairman, and Professor R. W. Sorensen, past president of the AIEE and now Professor Emeritus of the California Institute of Technology, Pasadena. Greetings were extended to the local Sections by AIEE President F. O. MacMillan, from Oregon State College in Corvallis. Professor Harold W. Bibber, Head of the Electrical Engineering Department at Union College in Schenectady, received the salutory remarks on behalf of the Schenectady Sections.

To demonstrate the speed with which present-day long-distance calls can be made, a large clock on the demonstration board ticked off the seconds from the time the party gave the operator the desired number to the time the person answered the phone. The average of all the calls placed was just under one minute, a far cry from the 14 minutes required by the type of long distance calling of 1925.

In his discussion of "Dialing Far-Away Places," M. S. Paige of the New York Telephone Company compares long distance telephoning through the years for the February 6 joint meeting of the AIEE and Institute of Radio Engineers Schenectady Sections. At the right, an operator at a portable switchboard is ready to place calls for members of the audience

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Communication Division

Committee on Television and Aural Broadcasting Systems (*J. B. Coleman, Chairman; I. J. Kaar, Vice-Chairman; W. L. Lawrence, Secretary*). The present standards of construction and installation for the outside plant equipment in this field are not considered adequate. An example of this is coaxial distribution cables entering into customers premises without any lightning protection. During the committee's recent meeting, at the AIEE Winter General Meeting, it was suggested that the field of ultrahigh-frequency television should offer some opportunities for papers. It was found necessary to cancel the previously planned session to demonstrate the various systems of color television at the 1952 Winter General Meeting in view of the stoppage by the Defense Mobilizer of production of such equipment. This committee is in need of a backlog of papers and subjects for future activities. Of timely interest would be a paper or papers on the method of supplying television signals to communities that now get only marginal signals.

Industry Division

Chemical, Electrochemical, and Electrothermal Applications Committee (*L. W. Roush, Chairman; J. Z. Linsenmeyer, Secretary*). The next general meeting of this committee will be held during the 1953 Winter General Meeting of the Institute at which time it is hoped that a new committee name will be decided upon which will not be so cumbersome but will be general enough to include the activities of all of its divisions.

Cathodic Protection. This division, under the supervision of Professor R. M. Wainwright, is preparing a series of articles on cathodic protection which ultimately may develop into a manual. The activities of the 5-year program are progressing satisfactorily. They include co-operation with other societies, railway signal systems, grounding practices, research and short courses in universities, instrumentation, and rectifiers. For the 1952 Summer General Meeting at Minneapolis, Minn., H. W. Walquist is preparing a paper entitled "Cathodic Protection for Hydroelectric Power Plants" which will be presented during the session sponsored by F. L. Lawton. In conjunction with the Chemical and Petroleum Industry Divisions, a session is planned on "Cathodic Protection for Refineries and Pipe Lines" at the 1952 Fall General Meeting in New Orleans, La. A committee meeting also will be held at that time.

Chemical Industry. A session will be held at the Summer General Meeting which will include "Fluorinated Chemicals for the Electrical Industry," and for the Pacific General Meeting at Phoenix a session will consider "The Chemical Industry in the West." In addition, F. S. Glaza will sponsor a session on "The Chemical Industry in the South" at the Fall General Meeting, while the Chemical Industry Committee, in conjunction with the Coal Mining Committee, is sponsoring sessions for the 1953 Middle Eastern District Meeting at Charleston, W. Va. In co-operation with Mr. Lawton, a session on "Chemical and Allied Industries in Western Canada" is being prepared for the 1953 Pacific General Meeting at Vancouver, British Columbia.

Electrochemical Processes. A session is being planned by W. E. Gutzwiller for the 1953 Winter General Meeting.

Electrothermal Processes. E. H. Browning will sponsor a session for the coming Summer General Meeting.

Petroleum Industry. J. Z. Linsenmeyer is sponsoring a session on "The Petroleum Industry in the South," continuing the work at New York on "Pipe Lines With Applications in Refineries."

Storage Batteries. "Recent Developments in Storage Batteries" will be the subject of a session sponsored by H. C. Riggs at the Minneapolis meeting. This division also is continuing its work on Standards.

Power Division

Committee on Transformers (*F. J. Vogel, Chairman; M. K. Brown, Vice-Chairman; J. R. Meador, Secretary*). This committee has a number of matters under consideration and in partial states of completion.

In the field of dielectric tests, a number of changes in both the Standards and the Test Code were presented as proposals to the Institute in an ACO paper. These have been acted upon by the Standards Committee and are in the hands of the American Standards Association. Some further changes have been proposed by the subcommittee, and will be presented to the Transformers Committee itself shortly. Discussion of changes in the dielectric tests and the form of the tables in the American Standards Association Standards are being considered.

Changes in the methods of making heat runs have been proposed and are about to be approved by the Transformers Committee for transmittal to the Standards Committee. Some further changes involving dry types are under consideration. Changes in temperature rise in dry-type transformers have been studied for some time, and co-operative tests on samples of Class *B* and Class *H* insulations are in progress.

The subject of noise is being studied to see if new methods of evaluating noise can be established. Little progress has been made to date, because it is an extremely difficult and complicated matter. A project on the reclaiming of oil is under consideration. A guide for the operation of dry-type transformers has been approved by the Transformers Committee and sent to the Standards Committee, with the proposal that it be presented for trial use for one year.

AIEE Subcommittee on the Application of Probability Methods to Power System Problems (*G. Calabrese, Chairman*). This subcommittee met during the recent AIEE Winter General Meeting in New York, N. Y. In 1950 the subcommittee initiated a survey of outage data of high-pressure boilers and turbines. The survey includes boilers with continuous rating of 200,000 pounds per hour or more of steam at a pressure of 700 pounds per square inch gauge or higher, and turbines operating at 700 pounds per square inch gauge or more having a capacity of 20 megawatts condensing 10 megawatts superposed. The data are collected under the auspices of the Edison Electric Institute. Replies have been received from about 70 companies. A preliminary report of the results of the survey obtained so far was discussed at the afore-mentioned meeting of the subcommittee. It is hoped that these results can be made available in the very near future in a subcommittee report to the Institute.

The subcommittee has under preparation a report covering a number of tables giving the probabilities of outages for groups of from 2 to 65 units and outage rates of: 0.005 to 0.0110 in steps of 0.001; 0.0100 to 0.0200 in steps of 0.0025; 0.0200 to 0.0400 in steps of 0.0050; 0.0400 to 0.0600 in steps of 0.0100; and also for an outage rate of 0.0220.

Science and Electronics Division

Committee on Computing Devices (*W. H. MacWilliams, Jr., Chairman; J. C. McPherson, Vice-Chairman; F. J. Maginniss, Secretary*). This committee, together with the Institute of Radio Engineers Electronic Computers Committee and the Association for Computing Machinery, held the Joint AIEE-Institute of Radio Engineers Computer Conference in Philadelphia, Pa., December 10–12, 1951. The conference (*EE, Feb '52, p 189*) surveyed the designs and performance of ten large-scale digital computers, including two British machines. The attendance was over 900. The papers and discussion are being published in a bound Review, which is scheduled to be ready for distribution by AIEE and Institute of Radio Engineers headquarters in March, at $3.50 a copy. The Review includes much supplementary design information that was not presented orally and should permit comparison of designs and also of experience.

Another computer conference, on input-output devices for computers, may be held in New York in December of 1953. A conference on the West Coast on small electronics computers is also under consideration.

The large-scale computer field is a complex and rapidly growing one, and comparisons among the various machines are hard to make. A set of yardsticks is needed to make comparisons valid and to assist designers of new equipments. A Subcommittee on Digital Computer Comparisons has been set up to consider this problem. A draft of a bibliography of computing devices literature has been circulated for review and preparation of one-sentence abstracts.

AIEE PERSONALITIES.....

D. A. Quarles Nominated for Institute President

Donald Aubry Quarles (AM '23, M '29, F '41), President, Sandia Corporation, Albuquerque, N. Mex., and Vice-President, Western Electric Company, Inc., New York, N. Y., has been nominated for the presidency of the AIEE for the 1952–53 term. Mr. Quarles was formerly Vice-President of the Bell Telephone Laboratories, Inc., New York, N. Y. He was born on July 30, 1894, in Van Buren, Ark., and was graduated from Yale University in 1916 with a bachelor of arts degree. During World War I he served with the United States Army for 2 years before he was discharged with the rank of captain. In 1919 he joined the Western Electric Company Engineering Department which, in 1925, became Bell Telephone Laboratories, Inc. From 1919 to 1924 he was in transmission engineering and research and then for four years he was a member of the Inspection Engineering Department in charge of apparatus inspection engineering. He was made Director of Outside Plant Development in 1929, and was in charge of the study of telephone materials and designs used in the outside plant and the development of new and improved materials and designs. As Director of Transmission Development from 1940 to 1944 he was in charge of the development of carrier telephone systems, broadband telephone and television systems, and improved voice frequency transmission systems. He was elected Vice-President of the Laboratories in 1947. Mr. Quarles is a member of many professional and engineering societies. He has served the Institute as Director (1944–48) and on the following AIEE committees: Finance (1944–48,

D. A. Quarles

Chairman 1946–48); Edison Medal (1945–47); Electronics (1945–47); Instruments and Measurements (1945–46); Planning and Co-ordination (1946–48); Headquarters (1946–48); Lamme Medal (1947–50); and Management (1948–52).

1951 Lamme Medal Awarded to A. E. Silver

Arthur Elmer Silver (AM '07, F '26, Member for Life), retired, Ebasco Services, Inc., New York, N. Y., has been selected to receive the 1951 AIEE Lamme Medal "for his pioneering of rural electrification by designing the simplified farm-type transformer combined with high voltage, long span, and common neutral line construction." Mr. Silver was born in Dexter, Maine, on August 14, 1879, and was graduated from the University of Maine in 1902 with a bachelor of science degree in electrical engineering. Following graduation he spent two years in the expert electrical course, Testing Department, General Electric Company, Schenectady, N. Y. In 1904 he entered the employ of the Raleigh (N. C.) Electric Company, in charge of the Meter Department. He was made electrical superintendent and chief engineer of the Carolina Power and Light Company in 1906 and held this position until 1910. Mr. Silver then became associated with the Engineering Department, Electric Bond and Share Company, New York, N. Y., and in 1919 he was made consulting electrical engineer in charge of all electrical engineering problems. In 1935 the service activities of the Electric Bond and Share Company for clients was transferred to a newly organized subsidiary, Ebasco Services, Inc., and he continued with this company as consulting engineer until his retirement in 1948. He is retained by Ebasco Services as associate consultant for advisory contacts. He has been active since 1915 in the work of the technical committees of the National Electric Light Association and its successor, the Edison Electric Institute, and is a member of the American Association for the Advancement of Science. He has served on the following AIEE committees: Telegraphy and Telephony (1920–22); Power Transmission and Distribution (1918–22, 1924–49); and Power Generation (1929–39).

A. E. Silver

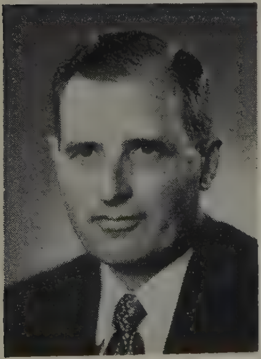
Vice-Presidential Nominees Are Hill, Hooven, Cassell, Lytle, and Ingledow

William Scott Hill (AM '25, M '30, F '50), supervising engineer, Power Transformer Engineering Department, General Electric Company, Pittsfield, Mass., has been nominated to serve the Institute as Vice-President representing the North Eastern District (number 1). Mr. Hill was born in Vicksburg, Mich., on September 6, 1902, and was graduated from the University of Nevada in 1923 with a bachelor of science degree in electrical engineering. After graduation he joined the General Electric Company Test Course in Schenectady, N. Y., and from 1924 to 1928 he was a member of the Central Station Engineering Department when he transferred to the New York City office as an application engineer. In 1939 he was made assistant district engineer and six years later became engineer of the Buffalo, N. Y., office. From 1945 to 1950 Mr. Hill was associated with Locke, Inc., as Vice-President of Engineering. In 1950 he again became associated with the General Electric Company. Mr. Hill has been a very active member of the AIEE and has served on the following Institute committees: Membership (1940–44); Constitution and Bylaws (1947–51); Sections (1948–50); Planning and Co-ordination (1950–52); Professional Division Advisory (1948–52, Chairman 1950–52).

Morris Daniel Hooven (AM '24, M '30, F '44), electrical engineer, Electrical Engineering Department, Public Service Electric and Gas Company, Newark, N. J., has been nominated to serve the Institute as Vice-President representing the New York City District (number 3). Mr. Hooven was born on May 30, 1897, in Weatherly, Pa., and was graduated from Bucknell University in 1920. After a year in the employ of the Westinghouse Electric Corporation he became manager of the Radio Department of the Robbins Electric Company, Pittsburgh, Pa. He became associated with the Public Service Electric Company in 1922 as one of a group engaged in the planning and design of the 132-kv system. He handled assignments in transmission and substation work, receiving the title of assistant transmission and substation engineer in 1939. Since 1942 he has held the position of electrical engineer, Electrical Engineering Department. Mr. Hooven is a member of the Institute of Radio Engineers and the National Society of Professional Engineers. He has served the AIEE as Director (1948–52) and on the following Institute Committees: Technical Program (1942–47, Chairman 1945–47, 1949–50); Planning and Co-ordination (1945–47, 1949–52, Chairman 1949–52); Institute Publicity (1945–47); Award of Institute Prizes (1945–47, Chairman 1945–47); Board of Examiners (1948–49); Edison Medal (1948–52); and Finance (1950–52).

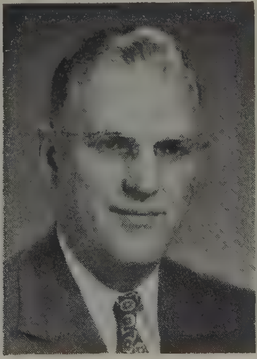
Wallace Lewis Cassell (AM '25, M '44), professor of electrical engineering, Iowa State College, Ames, has been nominated to serve the Institute as Vice-President representing the Great Lakes District (number 5). Born in Abilene, Kans., on June 19, 1899, Mr. Cassell received a bachelor of science degree in electrical engineering from the University of Colorado in 1922. In 1928 he received the degree of electrical engineer, also from the University of Colorado, and in 1946 he received a master of science degree in electrical engineering from Purdue University. Mr. Cassell was associated with various companies including the General Electric Company, Doughty and Welch Electric Company, Fall River, Mass., and the Mutual Radio Company, Wellesley, Mass., before joining the faculty of the University of Colorado in 1925. He became assistant professor in the Department of Electrical Engineering in 1928 and associate professor in 1932. In 1939 Mr. Cassell became associate professor in the Department of Electrical Engineering at Iowa State College and two years later was made professor. He is a member of Tau Beta Pi, Eta Kappa Nu, the Institute of Radio Engineers, and the American Society for Engineering Education. He served on the AIEE Education Committee (1947–49).

C. Myron Lytle (AM '31, M '42, F '51), manager of engineering, Kansas City (Mo.) Power and Light Company, has been

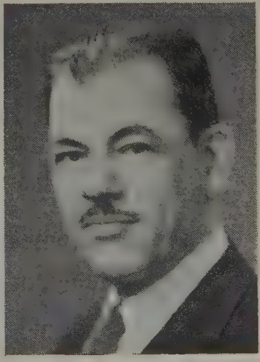


W. S. Hill

M. D. Hooven



W. L. Cassell



C. M. Lytle

Thomas Ingledow

nominated to serve the Institute as Vice-President representing the South West District (number 7). Mr. Lytle was born in St. Joseph, Mo., on March 27, 1903. He began his career with the Kansas City Power and Light Company in 1921 in the Voltage Operating Department. He was transferred to the Overhead System Engineering Department in 1922 and in 1933 was made superintendent of engineering and estimating. In 1948 Mr. Lytle was made chief engineer of transmission and distribution and a year later was appointed manager of engineering. He is a member of the National Society of Professional Engineers and in 1952 was President of the Missouri Society of Professional Engineers. He served the Kansas City Section of the AIEE as Secretary (1942–43), and as President of the Section (1946–47).

Thomas Ingledow (M '41, F '51), Vice-President and chief engineer, British Columbia Electric Company, Ltd., Vancouver, British Columbia, Canada, has been nominated to serve the Institute as Vice-President representing the North West District (number 9). Mr. Ingledow was born on March 11, 1899, in Cumberland, England, and received the degrees of bachleor of science and master of arts from the University of Glasgow. Mr. Ingledow's early experience included association with The Hydro Electric Power Commission of Ontario, Stone and Webster, Inc., and the Canadian General Finance Company. He joined Montreal Light, Heat and Power Consolidated in 1925 and served the company in various capacities for 15 years. In 1940 Mr. Ingledow became chief engineer, British Columbia Electric Company, Ltd., and four years later was appointed Vice-President. Mr. Ingledow is President of the Canadian Electrical Association, and past president of the Association of Professional Engineers of British Columbia. He is also a member of the Engineering Institute of Canada and has served the AIEE on the following Institute committees: Membership (1945–51); and the Special Committee to confer with the Engineering Institute of Canada (EIC) Committee on closer relationship between the EIC and AIEE (1943–46).

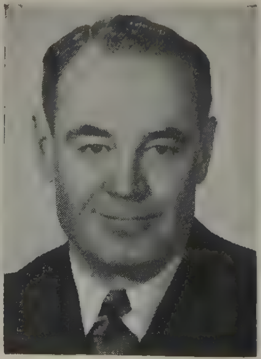
Muir, Pearcy, and Purnell Nominated for Directorships

Andrew C. Muir (AM '25, M '39), electrical engineer, The Berwind-White Coal Mining Company, Philadelphia, Pa., has been nominated to serve on the AIEE Board of Directors. Mr. Muir was born on October 12, 1903, in Turtle Creek, Pa., and was graduated from Carnegie Institute of Technology with a bachelor of science degree in electrical engineering in 1924. Following graduation, Mr. Muir was employed by the General Electric Company, Schenectady, N. Y., as a student engineer. Two years later he joined The Berwind-White Coal Mining Company and is electrical engineer for the company and its affiliated companies. Mr. Muir has actively served the Institute on the following AIEE committees: Industrial Power Applications (1942–47); Safety (1943–49); Sections (1943–48); Mining and Metal Industry (1946–51, Chairman 1951–52); Standards (1948–52); and Membership (1948–49).

Noah Clyde Pearcy (AM '24, M '30, F '43), chief electrical engineer, Pioneer Service and Engineering Company, Chicago, Ill., has been nominated to serve on the AIEE Board of Directors. Born in Jeffersonville, Ind., on December 5, 1898, Mr. Pearcy was graduated from Purdue University in 1922 with a bachelor of science degree in electrical engineering. Following graduation he entered the employ of the Westinghouse Electric Corporation, East Pittsburgh, Pa., as a student engineer, and upon completion of this course was employed in the research laboratory until 1924. In 1924 he became associated with the Louisville (Ky.) Gas and Electric Company as assistant electrical construction engineer and in 1926 was made electrical construction engineer. In 1929 he joined the Byllesby Engineering and Management Corporation of Chicago (Ill.), predecessor company of the Pioneer Service and Engineering Company, as assistant electrical engineer and in 1933 was appointed electrical engineer. Except for three years from 1937 to 1940, Mr. Pearcy has been associated continuously with this company and in 1948 he was appointed chief electrical engineer. He is a member of Eta Kappa Nu, Tau Beta Pi, and Sigma Xi. He has served the AIEE on the Automatic Stations Committee (1937–38) and was AIEE District Secretary (1945–46).

Clayton Spence Purnell (AM '29, M '35), eastern agency and construction manager, Agency and Construction Department, Westinghouse Electric Corporation, New York, N. Y., has been nominated to serve on the AIEE Board of Directors. Mr. Purnell was born in Frostburg, Md., on June 17, 1902, and received a bachelor of science degree in mathematics and physics from Washington College in 1922. He attended Carnegie Institute of Technology where he studied electrical engineering. Mr. Purnell became associated with the Westinghouse Electric Corporation in 1922 and was made transportation salesman in the New York City office in 1927, and industrial division salesman in 1937. He was made eastern district supervisor of the general industry section of the industrial division in 1946 and was given his present position in 1951. Mr. Purnell has just completed a term as Vice-President of the New York City District (number 3) of the AIEE and has served the Institute on the Finance, Sections, and Edison Medal Committees.

A. C. Muir


N. C. Pearcy

C. S. Purnell

N. S. Hibshman Nominated as Institute Treasurer

Nelson Sherk Hibshman (AM '27, M '32, F '41), Dean, School of Engineering, Pratt Institute, Brooklyn, N. Y., has been nominated to serve the AIEE as Treasurer. Mr. Hibshman was born on January 20, 1902, in Harrisburg, Pa., and was graduated from Pennsylvania State College with a bachelor of science degree in electrical engineering in 1924. In 1927 he received a master of science degree in electrical engineering from Lehigh University, Bethlehem, Pa., where he was a member of the faculty for 18 years. In 1942 he was appointed professor of electrical engineering and Chairman of the Electrical Engineering Department at New York University, which position he held until 1944 when he was appointed to his present position. He is a member of Eta Kappa Nu, Tau Beta Pi, and Sigma Xi. He served the AIEE as Vice-President representing the Middle Eastern District (number 2) from 1941–43 and has actively served on the following Institute committees: Instruments and Measurements (1937–39, 1942–44); Education (1941–42); Basic Sciences (1942–52); Lamme Medal (1946–49, Chairman 1948–49); Professional Group Co-ordinating (1948–49), Board of Examiners (1948–52); and Technical Program (1951–52).

N. S. Hibshman

H. F. McPhail (AM '19, F '42), Director, Power Utilization Branch, United States Bureau of Reclamation, Washington, D. C., has been appointed to the position of Assistant Commissioner of the Bureau.

Mr. McPhail entered the employ of the Bureau in 1919 and has been associated directly with the expansion of the hydroelectric capacity of the Bureau by the addition of Grand Coulee, Hoover, and Shasta power plants. When the Power Utilization Branch of the Bureau was established in 1943, Mr. McPhail became its Director. In 1948 he was chairman of the United States delegation to the International Conference of Large Electric Systems at Paris, France.

R. G. Rincliffe (AM '42), Executive Vice-President, Philadelphia (Pa.) Electric Company has been elected President of the company. Mr. Rincliffe joined the utility in 1923 as an engineering assistant. He has held various positions in the company including those of superintendent of gas manufacturing, purchasing agent, manager of electric generating stations, and Vice-President in charge of electric operations. He became a Director and Executive Vice-President in 1950. Mr. Rincliffe is a Vice-President of the Pennsylvania Electric Association and a member of the Edison Electric Institute, the American Gas Association, and The American Society of Mechanical Engineers.

Jacob Millman (AM '37, M '47), associate professor of electrical engineering, College of City of New York, N. Y., has been appointed professor of electrical engineering at Columbia University, New York, N. Y. Dr. Millman is an expert in the field of electronic circuits, pulse circuit techniques, and radar. He received the degrees of bachelor of science (1932) and doctor of philosophy (1935) from the Massachusetts Institute of Technology (MIT). He joined the faculty of the College of City of New York in 1936, becoming assistant professor in 1948. He developed seven patents in radar which have been assigned to the Federal government while he was serving on the staff of the Radiation Laboratory at MIT from 1942 to 1945.

Robert Paxton (AM '26, F '48), Vice-President, General Electric Company, Schenectady, N. Y., has been made a life trustee of Rensselaer Polytechnic Institute. Mr. Paxton is a graduate of Rensselaer and is presently serving as President of the Rensselaer Alumni Association.

E. C. Brown (AM '26, M '43), manager, Connecticut Valley Power Exchange, Hartford, Conn., has been appointed assistant to the president of the company. **D. Z. Stremalu** (AM '36), assistant manager, Connecticut Valley Power Exchange, Hartford, Conn., has been appointed manager, succeeding Mr. Brown. Mr. Brown is currently serving on the AIEE System Engineering Committee.

W. P. L'Hommedieu (M '38), Pacific Coast manager, Central Station Sales Department, Westinghouse Electric Corporation, San Francisco, Calif., has retired after 41 years in the West as the Westinghouse representative to the electrical utility industry. Mr. L'Hommedieu joined the company in 1906 after completing electrical engineering studies at Pratt Institute.

A. R. Hines (AM '45), manager, Michigan apparatus district, General Electric Company, Detroit, Mich., has been elected a commercial Vice-President of the marketing services division of General Electric. Mr. Hines has been associated with the company since 1921, and has been manager of the Michigan district office since 1949.

O. S. Mitchell (AM '23, M '30), secretary, Brazilian Traction, Light and Power Company, Ltd., Toronto, Ontario, Canada, has been appointed Vice-President of the company's operating subsidiaries. His headquarters will be in Rio de Janeiro, Brazil.

G. A. Porter (M '49), chief power plant engineer, and **H. P. Seelye** (AM '19, F '43), chief engineer, Engineering Department, both of The Detroit Edison Company, Detroit, Mich., have been appointed to the positions of manager of construction and manager of engineering respectively. Mr. Seelye served on the AIEE Domestic and Commercial Applications Committee (1941–50).

Paul Baran (AM '50), development engineer, Raymond Rosen Engineering Products Company, Philadelphia, Pa., has been appointed field engineering representative for the Audio and Video Products Corporation, New York, N. Y. Mr. Baran is a member of the Institute of Radio Engineers.

R. S. Kersh (AM '42, M '45), manager, Central Station Sales Department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been elected Executive Vice-President of the company. Mr. Kersh has been associated with Westinghouse for 22 years. He is a member of The American Society of Mechanical Engineers.

D. B. Terwilliger (AM '37, M '49), electromechanical design engineer, Aircraft Armaments, Inc., Baltimore, Md., has been made chief electromechanical engineer. Mr. Terwilliger's previous experience includes association with the Glenn L. Martin Company as a project engineer. He joined Aircraft Armaments, Inc., in 1951.

Joseph McOrlly (M '39), chief engineer, Engineering Department, Edwin L. Wiegand Company, Pittsburgh, Pa., has been appointed Vice-President in charge of engineering. Mr. McOrlly joined the company in 1935 as an electrical engineer.

A. M. Jacobs (M '18), Chairman, Electricity Supply Commission, Johannesburg, Africa, has retired. Mr. Jacobs has been associated with the Commission since 1923 and had been Chairman since 1948. He is a past president of the South African Institute of Electrical Engineers.

H. C. Blair (AM '50), application engineer, transformer section, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been assigned to the company's New Orleans, La., district office.

C. L. Bean (AM '39, M '47), engineer-inspector, Communication and Signal Department, Seaboard Air Line Railroad Company, Norfolk, Va., has been appointed electrical engineer for the company.

S. A. Smith, Jr. (AM '24, M '31), Vice-President, General Cable Corporation, Bayonne, N. J., has been elected Treasurer of the company.

H. A. Bergen (AM '51), project engineer, Stemar Company, Chicago, Ill., is now associated with the Belmont Radio Corporation, Chicago, Ill. He is on the engineering staff.

OBITUARY • • • • • •

Blake D. Hull (AM '15, M '26, F '39, Member for Life), retired, Southwestern Bell Telephone Company, Dallas, Tex., died on February 15, 1952. A past president of the AIEE, he was born on September 12, 1882, in Galesburg, Mich., and received a bachelor of science degree in electrical engineering from the University of Kansas in 1905. The next six years Mr. Hull was assistant construction engineer and transmission engineer for the Missouri and Kansas Telephone Company. In 1912 he began his career with the Southwestern Bell Telephone Company as general transmission and protection engineer. After various promotions, Mr. Hull was made chief engineer of the company with headquarters in St. Louis, Mo. He held this position until his retirement in 1947. Mr. Hull was past president of the AIEE (1947–48) and served as Director (1931–35) and as Vice-President (1928–30) of the Institute. He served actively on the following AIEE committees: Communications (1928–35); Technical Program (1932–35); Institute Policy (1938–40); Transfers (1945–47); Executive (1947–49); Edison Medal (1947–48); John Fritz Medal Board of Award (1947–52); Members-for-Life Fund (1950–51); Constitution and Bylaws (1950–51).

B. D. Hull

Morris Evans Leeds (AM '01, F '26, Member for Life), Chairman of the Board, Leeds and Northrup Company, Philadelphia, Pa., died on February 8, 1952. He was born on March 6, 1869, in Philadelphia, and was graduated from Haverford College

M. E. Leeds

in 1888 with a bachelor of science degree. He joined the James W. Queen and Company, a scientific instrument company, in 1890 and was connected with this firm for nine years, after which he founded his own business, the Morris E. Leeds and Company, which in 1903 became the Leeds and Northrup Company. Mr. Leeds was well-known in the field of industrial relations having been cited by the Institute of Management for the "use of management skills in service in the community." He was the Edison Medalist for 1948 and was the recipient of many other scientific awards including the Edward Longstreth Medal of the Franklin Institute. He was a fellow of the American Association for the Advancement of Science and a member of the American Society for Testing Materials, the American Physical Society, the American Academy of Arts and Sciences, the American Society for Metals, and the Franklin Institute.

Lyle Bradford Robinson (AM '23, M '28), central station application engineer, General Electric Company, Seattle, Wash., died on November 1, 1951. He was born on January 7, 1893, in Momence, Ill., and was graduated from the University of Washington in 1917 with a bachelor of science degree in electrical engineering. He joined the General Electric Company in 1917 and, except for a period when he served as a captain in the United States Army during World War I, he served with the company continuously. Mr. Robinson received his sales training in Pittsfield, Mass., and in 1923 was transferred to Seattle as sales engineer. He served as transformer specialist and in 1950 was appointed central station application engineer for the company. He was very active in the Seattle Section of the AIEE, having served as student activity committee chairman during the past year.

Howard Milton Bliem (AM '16, M '28, Member for Life) engineer, electrical division, United States Bureau of Reclamation, Denver, Colo., died on October 8, 1951. He was born on October 28, 1889, in San Antonio, Tex., and was graduated from Lafayette College with an electrical engineering degree in 1913. From 1913 to 1916 Mr. Bliem was associated with the San Antonio Gas and Electric Company where he was general foreman of construction. For the next two years he was an electrical designer with the Texas Power and Light Company, Dallas, and from 1918 to 1920 Mr. Bliem was employed by the Texas Construction Company, also of Dallas, as an electrical designing engineer. He joined the Bureau of Reclamation in 1921 as assistant engineer and after several promotions became head of the specifications section of the electrical branch of design and construction.

Emerson Wood Thomas (AM '38), electronic scientist, radio division, United States Naval Research Laboratory, Washington, D. C., died on October 24, 1951. He was born in Washington, D. C., on December 6, 1914, and was graduated from George Washington University in 1937 with a bachelor of science degree in electrical engineering. He was an instructor at the Capitol Radio Engineering Institute, Washington, until 1944, at which time he became associated with the Tobe-Deutschmann Company, Canton, Mass., as a research engineer. Since 1948 he had been employed by the Naval Research Laboratory as an electronic scientist.

Ira Vincent Ragsdale (M '47), electrical engineer, Power Operations Department, Tennessee Valley Authority, Knoxville, died on January 22, 1952. He was born on August 25, 1896, in Jamestown, Ind., and received the degree of bachelor of arts from Wabash College, Crawfordsville, Ind., in 1926 and the master of arts degree from the University of Tennessee, Knoxville, in 1932. Mr. Ragsdale was on the faculty of the foregoing schools and the University of Chicago (Ill.) for 16 years. He joined the Electrical Laboratory and Test Branch of the Tennessee Valley Authority in 1942 and in 1950 transferred to the electrical design branch where he supervised the design of communication systems for hydro and steam generating plants.

William Nelson Shoch (AM '29, M '46), branch engineer, Philadelphia (Pa.) Electric Company, died on January 29, 1952. He was born in Kelton, Pa., on July 6, 1893, and attended Drexel Institute of Technology. He began his career in the Philadelphia Electric Company in 1917 as a laboratory assistant and served continuously with the company in various capacities for 35 years. He was a member of the Pennsylvania Society of Professional Engineers.

Benjamin Leonard Wise (AM '45), Executive Department, National Electric Welding Machines Company, Bay City, Mich., died on February 15, 1952. He was born on January 5, 1905, in Greensburg, Pa. His business experience included association with the Westinghouse Electric Corporation, Pittsburgh, Pa., and The Federal Machine and Welder Company, Warren, Ohio. Mr. Wise was a member of the American Welding Society and had served on the AIEE Electric Welding Committee since 1945.

MEMBERSHIP • • • •

Recommended for Transfer

The Board of Examiners at its meeting of February 21, 1952, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary of the Institute. A statement of valid reasons for such objections, signed by a member, must be furnished and will be treated as confidential.

To Grade of Member

Barnum, R. T., supervisor, Westinghouse Electric Corp., Denver, Colo.
Benjamin, A., asst. distribution engr., Quebec Hydro-Electric Comm., Montreal, Que., Can.
Bjontegard, A. M., engr., General Electric Co., Lynn, Mass.
Blinn, E. F., chief draftsman, N. Y. Shipbuilding Corp., Camden, N. J.
Buck, C. M., asst. engr., Pacific Gas & Electric Co., Emeryville, Calif.
Campbell, W. J., elec. engr., The Detroit Edison Co., Detroit, Mich.
Carvill, A. L., meter sales mgr., General Electric Co., West Lynn, Mass.
Cockerell, R. L., elec. distribution supt., National Light & Power Co., Moose Jaw, Sask., Can.
Collis, H. O., co-ordinator, Owens-Corning Fiberglas Corp., New York, N. Y.
Daniel, C. A., mgr., General Electric Co., Beaumont, Tex.
DeCarlo, C. F., elec. engr., Design & Development Co., New York, N. Y.
Diederich, N. M., elec. engr., Clark Controller Co., Cleveland, Ohio
Foster, G. E., chief engr., Metrotype Corp., Chicago, Ill.
French, A. D., engr., General Electric Co., Schenectady, N. Y.
Galopin, F. E., factory liaison engr., Sylvania Electric Products, Inc., Danvers, Mass.
Gillam, C. E., engr., Kansas City Power & Light Co., Kansas City, Mo.
Grauch, W. F., transmission & distribution supt., Niagara Mohawk Power Corp., Niagara Falls, N. Y.
Hill, S. W., div. engr., Oklahoma Gas & Electric Co., Oklahoma City, Okla.
Jordan, H., chief engr., Given Manufacturing Co., Los Angeles, Calif.
Judd, R. C., asst. mgr., Iowa-Illinois Gas & Electric Co., Davenport, Iowa
Kittrell, L. W., div. engr., Southwestern Gas & Electric Co., Shreveport, La.
Lago, G. V., asst. prof. of elec. engg., University of Missouri, Columbia, Mo.
Lamm, A. U., engg. mgr., Allmanna Svenska Elektriska Aktiebolaget, Ludvika, Sweden
Latham, C. H., exec. vice-pres., Monongahela Power Co., Fairmont, W. Va.
Lister, C. A., development engr., Electric Controller & Mfg. Co., Cleveland, Ohio
Peel, J. A., commercial engr., General Electric Co., West Lynn, Mass.
Potter, K. W., engr., Public Service Co. of Colorado, Grand Junction, Colo.
Pritchett, J. D., elec. engr., genl. hdqtrs., Far East Command, %PM, San Francisco, Calif.
Raney, E. A., manufacturing specialist, General Electric Co., Pittsfield, Mass.
Ray, L. L., design engr., General Electric Co., Fort Wayne, Ind.
Robinson, J. A., western editor, *Electrical World* Magazine, San Francisco, Calif.
Russell, W. H., USA engr., Corps of Engineers, Portland, Oreg.
Sahlman, F. M., mgr., Washington Electric Cooperative, Inc., East Montpelier, Vt.
Schaibly, H. M., head starting engr., Commonwealth Edison Co., Chicago, Ill.
Schall, G. E., Jr., assoc. elec. engr., Underwriters' Laboratories, Inc., New York, N. Y.
Shields, A. B., elec. engr., Addressograph-Multigraph Corp., Cleveland, Ohio
Small, F. R., toll practices supervisor, Southwestern Bell Telephone Co., St. Louis, Mo.
Stumpf, G. H., elec. engr., Otis Elevator Co., New York, N. Y.
Taylor, R. W., Knoxville area operating supt., Tennessee Valley Authority, Knoxville, Tenn.
Truesdell, F. W., div. engr., General Electric Co., Lynn, Mass.
Turner, J. T., Jr., transportation maintenance mgr. B. C. Electric Railway Co., Vancouver, B. C., Can.

41 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should supply a signed statement to the Secretary before April 25, 1952, or June 25, 1952, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Carter, T. J., The British Thomson-Houston Export Co., Ltd., Rugby, England, c/o Wilson, Sons & Co., Ltd., Sao Paulo, Brazil, S. A.
Stoddard, W. S. (re-election), New England Power Co., Worcester, Mass.
Tirunarayanan, M. S., Indian Institute of Science, Bangalore, India

3 to grade of Member

OF CURRENT INTEREST

Navigational Crystal Ball Helps Mariners Avoid Collisions at Sea

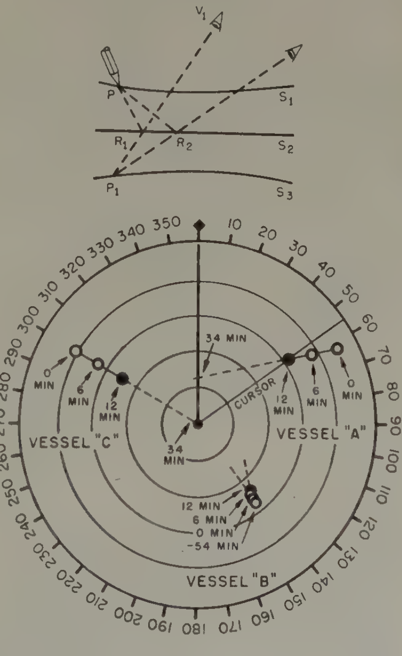
A navigating crystal ball now makes it possible for a mariner to interpret more accurately the movements of nearby vessels and lets him know in advance whether his ship is headed for clear sailing or disaster.

The revolutionary device, called the reflection plotter and developed by the Raytheon Manufacturing Company, Waltham, Mass., is used in conjunction with the shipboard radar system. It provides the radar with a visual course and speed-recording feature that permits the navigator to keep track of all vessels within danger range, and to plot the course and progress of those likely to cross, meet, or overtake him.

During the past several years, with the increased use of radar and its wider application to commercial and private vessels, it has become apparent that the capabilities of the system are far greater than their present utilization would indicate. That these potentialities have not yet been fully realized has been due, in large part, to the inability of the radar operator to remember accurately the positions of vessels detected by the ship's radar, and the absence of a quick and easy method to transfer the information provided by the radarscope, indicating the actual position of other ships, to a maneuvering board, and then to translate this information to learn their positions relative to his own vessel. Use of the new reflection plotter as shown in the picture eliminates the necessity of either remembering the information or of transferring the information to a maneuvering board. This is accomplished by allowing the operator to plot the actions of the ships, in effect, directly upon the face of the radarscope.

The reflection plotter provides a nonreflecting plotting surface, which is fitted over the 16-inch radar screen. Edge lighting around the plotter illuminates any objects placed in contact with it, so that by using a grease pencil, marks made on the plotter become luminous. Through an optical arrangement, these notations appear as though they actually are being made on the face of the radar screen below, so that the luminous radar "pips" can be marked and their actions observed. Their movements away from the original marked positions enable the operator to determine the direction and speed of each vessel in relation to that of his own ship.

A special hood arrangement over the plotter shields the surface from outside light so that the operator can observe the radar screen and perform his plotting operation without interference from the normal illumination on the ship's bridge.



The upper sketch shows the curved surfaces of the plotter by means of which parallax is avoided. The lower sketch shows how ships' positions are plotted to determine their courses and so avoid collision

S_1, the top and plotting surface, is curved just to match that of the plan-position-indicator (PPI) screen and is made of a nonreflecting plastic (see the upper part of the diagram). S_2 is a partially reflecting glass plate and is placed midway between S_1 and S_3, the PPI screen. The perpendicular distance S_1-S_2 is equal to S_2-S_3 (due to the curvature of S_1 being exactly opposite S_3). If a pencil were placed at point P and the eye of the viewer were at V_1, light rays originating at P will strike S_2 at R_1. Part of these rays will be reflected to V_1. To the eye, this will appear to have originated at a point on an extension of the line V_1-R_1, and, since S_1-S_2 and S_2-S_3 are equidistant, then the point P will appear to be on the face of the PPI at P_1, and this P_1 will be directly below P. It is apparent that, if the position of the eye were changed to V_2, the location of P_1 will not change; therefore, the effect of parallax will be eliminated. If a flat plotting surface were used, the distance S_1-S_2 and S_2-S_3 would not always be equal, and a parallax error would be produced, thus the reason for the curved plotting surface.

Positions and course indications are marked on the face of the reflection plotter, using a special combination illuminated grease pencil and plotting scale

An edge-lighting ring around S_1 will illuminate any object placed in contact with it; therefore, by using a grease pencil to mark this top surface, all targets on the face of the PPI may be plotted. With this technique, radar targets may be tracked and their future positions extrapolated as would be accomplished on any plotting board, and at the completion of a navigation

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Future Meetings of Other Societies

American Electroplaters' Society. 39th Annual Convention. June 16–20, 1952, Conrad Hilton Hotel, Chicago, Ill.

American Society for Quality Control. Sixth Annual Convention. May 22–24, 1952, Syracuse, N. Y.

American Society for Testing Materials. Annual Meeting. June 23–27, 1952, Hotel Statler, New York, N. Y.

Edison Electric Institute. 20th Annual Convention. June 2–5, 1952, Cleveland, Ohio

Hydraulic Institute. June 1–3, 1952, The Cloisters, Sea Island, Ga.

Institute of Radio Engineers. Fourth Southwestern Conference and Radio Engineering Show. May 16–17, 1952, Rice Hotel, Houston, Tex.

International Lighting Exposition and Conference. Fourth Annual Meeting. May 6–9, 1952, Cleveland Auditorium, Cleveland, Ohio

International Organization for Standardization. Triennial Meeting. June 9–21, 1952, Columbia University, New York, N. Y.

Metal Power Show. Eighth Annual Meeting. April 29–30, 1952, Drake Hotel, Chicago, Ill.

National Air Pollution Symposium. May 5–6, 1952 Huntington Hotel, Pasadena, Calif.

National Association of Electrical Distributors. 44th Annual Convention. June 9–13, 1952, Atlantic City, N. J.

National Fire Protection Association. Annual Meeting. June 9–13, 1952, Hotel Statler, New York, N. Y.

Pennsylvania Electric Association. Spring Meeting, Electrical Equipment Committee. May 15–16, 1952, Hotel Roosevelt, Pittsburgh, Pa.

The American Society of Mechanical Engineers. Semiannual Meeting. June 15–19, 1952, Sheraton-Gibson Hotel, Cincinnati, Ohio

The Electrochemical Society Inc. 50th Anniversary Meeting. May 4–8, 1952, Benjamin Franklin Hotel, Philadelphia, Pa.

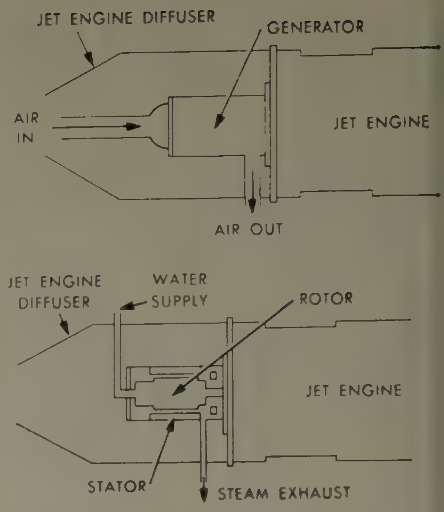
problem the grease pencil markings easily may be wiped away.

The bearing cursor of the radar is placed between S_2 and S_3 so that bearings of targets and plotted points may be taken in the same manner as is used normally with the radar. The radar range rings and travelling-range mark information may be similarly utilized for range data.

On the well-lighted bridge of a ship the ambient illumination may be of a sufficiently high level so that a close-fitting viewing hood normally would be used with the radar. For these instances a special hood has been developed to reduce ambient light but permit simple plotting.

The radarscope picture in the lower diagram shows how the relative positions of vessels can be plotted directly on the reflection plotter. Positions of target ships are circled at 6-minute intervals. Vessel *A*, for instance, has shown no change of course in relation to the radar-equipped ship (center of scope); hence it will cross the course of the radar ship in 34 minutes, approximately 2$^1/_2$ miles ahead, as shown by the extended dotted line. Vessel *B* is slowly overtaking, but its position at the 12-minute plot shows it has altered its course and will pass well abeam of the radar ship. Vessel *C*, as indicated by the plots showing its position relative to the radar ship, is on a collision course, with only 34 minutes remaining for appropriate action.

New Environment-Free Alternator Developed Using Water Coolant



At the top is shown a conventional alternator which is blast-cooled. The drawing below shows an environment-free alternator which is water-vaporization cooled

An alternator, said to be the first successful vaporization-cooled, environment-free alternator in the industry, maintains satisfactory cooling while operating in extreme conditions of temperature and altitude. Developed in connection with North American Aviation's guided missile research program, the new alternator is the result of Jack and Heintz, Inc., research on power units that offer environment-free operation and impose a minimum penalty on the aircraft.

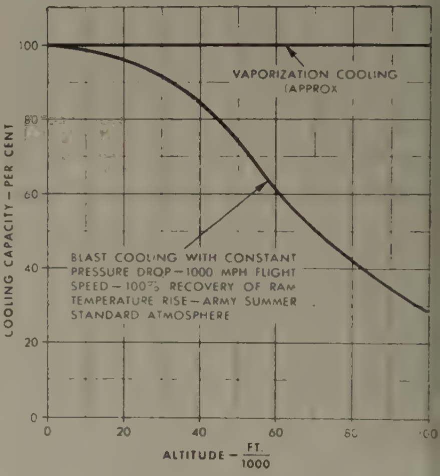
Conventional design approaches were discarded in developing this alternator, since air-blast and fan methods of cooling have well-known limitations at high speeds and altitudes. With the vaporization cooling system, the new alternator and its water supply are isolated thermally from environment.

The alternator, 93 per cent efficient, requires 3$^1/_2$ pounds of water per hour at rated load. However, its operation is limited to a cycle which depends on the capacity of the coolant reservoir, whose size is limited by weight and space available in the aircraft.

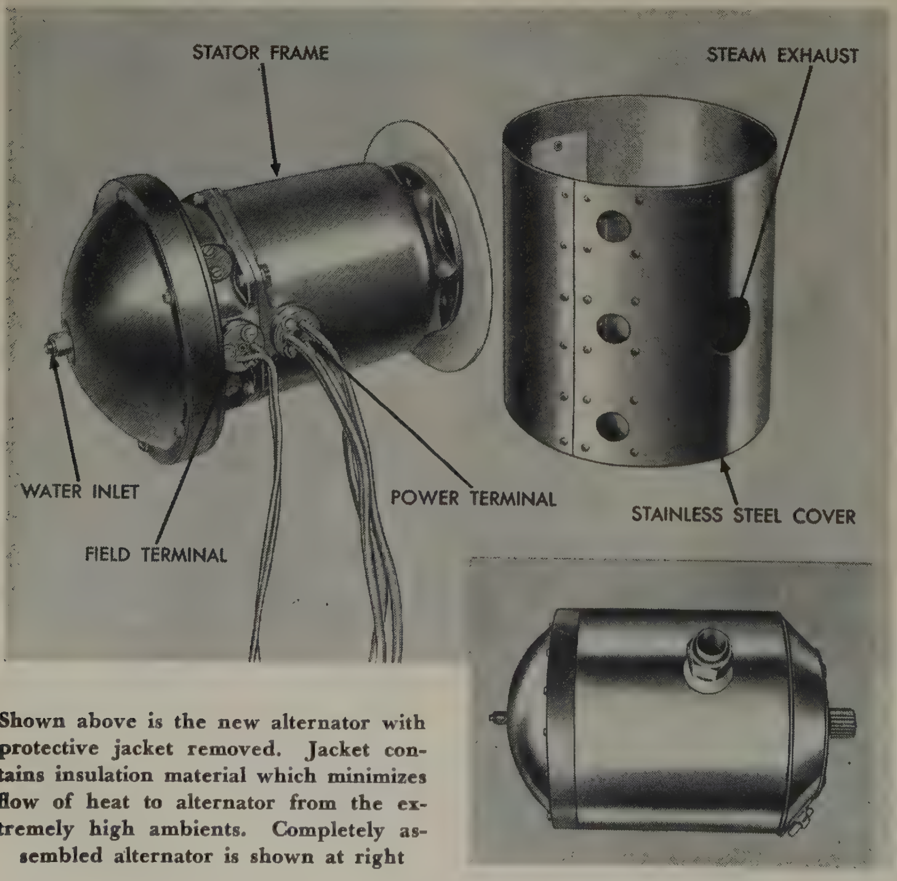
In operation, coolant from the reservoir is injected into the alternator's hollow shaft under pressure. Centrifugal force propels the water through four ports in spray form, and scatters it on the internal surfaces of the machine. As it picks up heat from these surfaces, the water vaporizes to become the coolant. Resultant steam is exhausted through a port. Water inlet flow is regulated automatically by a special valve which is controlled by a temperature-sensing element in the alternator.

The 3-phase 400-cycle 12,000-rpm unit is rated at 12 kva but it can deliver 16 kva and maintain satisfactory cooling. Conventionally cooled alternators will maintain safe operating temperatures without derating at altitudes only up to 35,000 feet.

Field power for the machine is taken from the output leads through slip rings and brushes, passes through the rectifier bank and magnetic amplifier of a specially designed exciter-voltage regulator, and then to the field. The exciter-voltage regulator, used because existing lightweight carbon-pile-type regulators would not meet the environmental conditions encountered, is of the magnetic-amplifier type. This regulator has no moving parts, provides excellent response time, and may be adapted for either blast or vaporization cooling.



As aircraft altitude increases, cooling capacity of conventional air-blast cooled alternators drops off, as shown. In contrast, cooling capacity remains constant in alternator cooled by vaporization



Shown above is the new alternator with protective jacket removed. Jacket contains insulation material which minimizes flow of heat to alternator from the extremely high ambients. Completely assembled alternator is shown at right

Commutation problems are minimized in the alternator since the steam atmosphere acts as a lubricant between the brushes and slip rings, prolonging brush life. Flow of ambient heat to the alternator, which is extremely high at missile and jet-aircraft speeds, is minimized by insulation placed between the stator and the outside shell of the alternator.

The alternator has a power factor of 80 per cent, weighs 39 pounds, is $12^5/_8$ inches long and 9 inches in diameter. It is an engine-mounted unit with a 6-inch flange diameter and a 5-inch bolt circle diameter. Some of the other advantages of this water-vaporization cooled alternator are: Heat-transfer coefficients for boiling water are 20 to 200 times that for air. High heats of vaporization tend to keep the weight of the coolant required at a reasonably low value of 3.4 pounds per hour per kilowatt of losses. On flights of short duration, the total weight of coolant required is much less than the lifting capacity taken away from the airplane by blast-cooling drag.

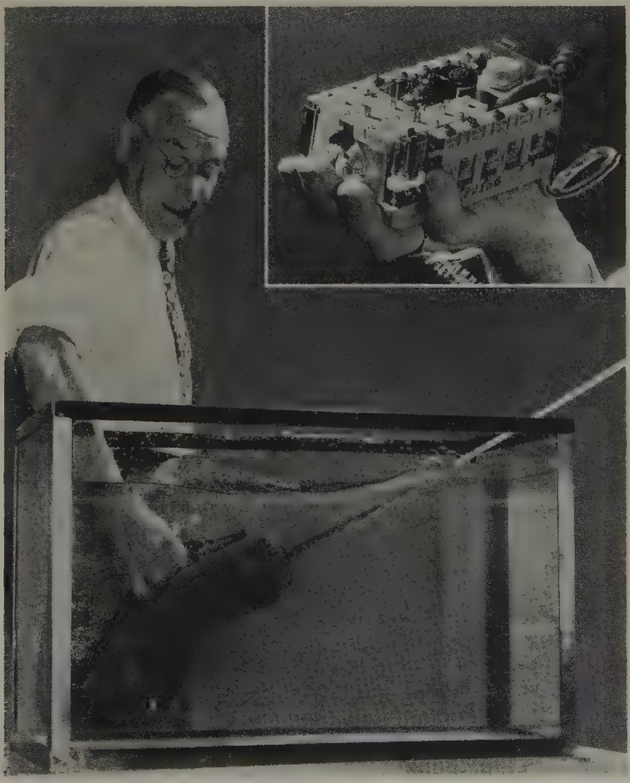
On expendable or short-duration flights, no control is required except a simple orifice set to meet full-load cooling requirements. Water can be kept from freezing, where necessary, by storing in a separate container—for example, in the oil reservoir. Low-freezing-point evaporants may be used.

New Walkie-Talkie Uses Subminiature Vacuum Tubes

The lightest and most compact hand radio transmitter-receiver, smaller than a loaf of bread, developed by the Raytheon Manufacturing Company, Waltham, Mass., with the Signal Corps Engineering Laboratories in 1948, is the first communications equipment to utilize tiny subminiature tubes on a mass production basis. It is a complete one-package transmitter, receiver, battery power-source, and antenna, designed for a specific, highly essential purpose: to link front-line troops with other men and other units.

There were handie-talkies in World War II but the new model, officially designated the *AN/PRC-6*, has a number of outstanding advantages over its predecessor. With most of its metal parts built of magnesium and aluminum, the unit weighs but $6^1/_2$ pounds, including a $3^1/_2$-pound battery, approximately one-half as heavy as the former 11-pound model. The tiny set can be held comfortably in the palm of one hand when it is taken out of its case. It uses frequency modulation and can be adjusted in the field to any one of 44 frequencies. It can be used over distances greater than the World War II model. In the roughest terrain it can operate effectively up to one mile, and has a normal range of one to three miles, depending on terrain conditions. The old handie-talkies had a reliable range of less than one mile.

The unit is rugged enough to withstand submersion indefinitely in water and to operate in temperatures from −40 degrees to +131 degrees Fahrenheit. During a demonstration, sets actually were plunged into a tank of water to demonstrate their resistance to submersion, and later placed in a huge refrigerator where they underwent extreme low-temperature tests.



The small transmitter-receiver section of the new walkie-talkie radio set can be held easily in one hand, as shown in the insert. The set will operate efficiently after being indefinitely submerged in water and in temperatures from −40 degrees to +131 degrees Fahrenheit

The subminiature tubes used in the equipment made possible the development and production of the new hand communications unit, and are so tiny that operators must use microscopes in assembling them.

Sea Rescues Made by Air-Borne Radio-Controlled Lifeboats

The completion of final acceptance tests on a new radio control for an air-borne lifeboat that can be dropped by parachute from an airplane and unerringly guided to survivors in the water was announced recently by the Westinghouse Electric Corporation.

An electric control system that uses the radio signal from the air to control the engine and equipment for driving and steering the boat has successfully passed trial runs as well as final tests conducted by the United States Air Force at Mobile, Ala. After the lifecraft is dropped by parachute into the sea from the rescue airplane, radio signals at five different frequencies take over complete control in individual stages. The stabilizing fins that hold the boat steady as it leaves the plane are jettisoned. A guard protecting the propeller and rudder is freed. The engine air vents are opened. The motor is cranked up and automatically choked. Following this, the clutch is engaged and the throttle advanced to send the craft forward under the guidance of the radio controller.

When the lifeboat reaches the survivors, the air-borne operator can bring it to a halt until the survivors board and then set the boat on its course again. If the physical condition of the rescued men is good, they can take over control of the boat themselves. If they are too weak for this activity, the air-borne operator can guide them to shore or a rescue surface ship. The boat is equipped with triple controls, permitting passengers to break off radio control at any time and operate it electrically or manually.

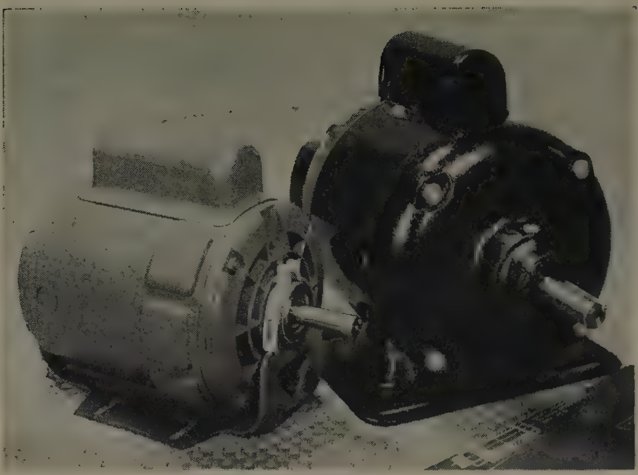
An electric control system incorporating electronic amplifiers, relays, and actuators activates the boat's power plant. Each signal is used to perform a specific group of functions, and the electric control system is so designed that it carries out each duty separately and in the proper order.

The 3,500-pound craft can hold 15 men with provisions for 10 days and fuel for an 800-mile cruise. It is also equipped with walkie-talkie radio sets for boat-plane communications, a machine for distilling fresh drinking water from sea water, and a zipper canopy to protect survivors against the boiling sun.

Progress in Small Motor Design Features Lightness, Versatility

A new line of fractional horsepower motors has been developed which makes use of some new concepts in design to provide as much as 50 per cent less weight per horsepower and considerably smaller size than present motors. In addition, the versatility of the motor has been broadened and its appearance modernized.

The main features of this improved design which make possible the lighter



Comparison of one of the new totally enclosed fan-cooled motors (left) and its predecessor of equivalent rating. In some models, the new motor may weigh less than half as much as the motor which it replaces

weight and smaller size are a balanced electrothermal design, more effective ventilation, and generous use of aluminum for structural parts. On the standard 4-, 6-, and 8-pole motors, double-end ventilation is used, with a complete ventilation assembly provided at each end of the motor. The higher speed 2-pole motors have a through ventilation system in which air is drawn in at one end of the motor and through passageways over the stator core to the exhaust at the other end. For totally enclosed motors, a completely self-contained fan-cooling system is used in which an internal ventilation system provides for effective heat transfer to the motor shell and a separate system—sealed off from the first—washes the outer surface of the motor with a constant stream of air. This innovation makes it possible to build open motors in the same frame diameter as totally enclosed motors.

No cellulose or other natural insulating materials have been used in this design. Nylon is used for slot liners and phase insulation. This, combined with Formex insulated wire and Glyptal varnish, will provide a long-life insulation that is extremely resistant to moisture. While no increase in maximum operating temperatures is advocated for these motors, the new insulation will increase significantly the safety factor in so far as abnormal conditions and accidental overloads are concerned.

An ingenious sleeve and thrust bearing design, with provision for complete oil retention and recirculation regardless of the position of the bearing or the direction of the load, makes it possible to operate these motors in any position. Oil capacity is more than 50 per cent greater than present designs, and improved oil retaining and transmitting materials increase the flow of lubricants to the bearings. Both sleeve-bearing and ball-bearing types will be available.

Developed by the General Electric Company's Fractional Horsepower Motor Department, this new line of motors will be available in a variety of ratings in polyphase, capacitor start, split phase, and permanent split capacitor types.

Eta Kappa Nu Award to Purdue Chapter

Winner of the Eta Kappa Nu Achievement Award for 1950–51 is the Beta Chapter of Purdue University. This is the second award plaque this chapter has received, the first being for the academic year 1933–34. At the presentation ceremonies on February 12, 1952, were, from left to right: E. M. Sabbagh (M '35), Faculty Adviser; Stanley Jacke and J. E. Erwin, past presidents of the Beta Chapter of HKN; E. T. B. Gross (F '48), Member, National Advisory Board of HKN, who made the presentation; F. L. Hovde, President, Purdue University; Sigurd Kristiansen, and H. H. Davis, President and Vice-President of Beta Chapter HKN; D. D. Ewing (F '21), Head, School of Electrical Engineering, Purdue; O. W. Eshbach (F '37), National President of HKN

W. F. Libby Receives 1951 Research Corporation Award

High in the stratosphere a chemical process is going on which has resulted in an accumulation on the earth of about 80 tons of radioactive carbons. Dr. Willard Frank Libby, University of Chicago, received the 1951 Research Corporation Award for developing a method and apparatus to measure the residual carbon radioactivity in archeological specimens and thus determine their ages with an accuracy hitherto unknown.

Dr. Libby's contribution is one of the most important advances of the century in archeological progress. His award from Research Corporation is one of less than a dozen since they were instituted in 1925. The presentation, consisting of a plaque, citation, and $2,500, was made by Dr. Joseph W. Barker, president and chairman of the foundation, at a dinner in New York City, February 26.

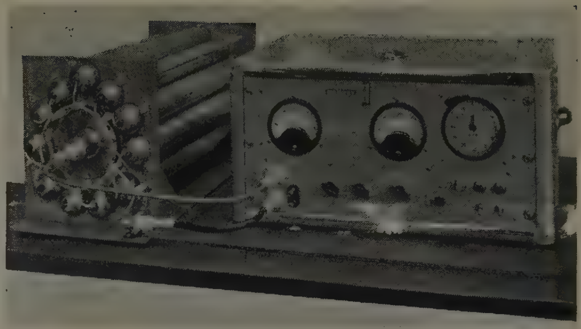
The dinner also marked the 40th anniversary of establishment of the foundation by Dr. Frederick Gardner Cottrell to disburse its net income on advancement of science. Its first patent income derived from Dr. Cottrell's invention of a method for removing solids from smokestack gases by electrical precipitation. Subsequent patents administered include those for Vitamin *B* and cortisone.

Dr. Libby said in accepting the award that his method of dating is based on the known inventory of 80 tons of radioactive carbon atoms in the world. His studies so far have set the Ice Age at 10,000 years ago instead of 25,000 years, dated the world's oldest village, confirmed the date of one of the oldest known Biblical manuscripts, and contributed vital dates to the history of the first men in America.

The radiocarbon is produced in a series of natural atom-smashing events at their most active approximately 8 miles above the earth's surface. Carrying energy thousands of times greater than produced by man-made atom smashers, cosmic rays enter the atmosphere from outer space to shatter the nuclei of atoms of atmospheric gases. Other reactions take place subsequently to result in carbon dioxide absorbed by plants and, in turn, eaten by animals. At death of the animal or vegetable matter, the radioactive carbon content is no longer replenished by food intake and the activity of the residual radiocarbons can be measured by Dr. Libby's special apparatus involving the principle of Geiger counters to determine how long before that the specimens were alive.

This apparatus shown in the picture consists of a ring of 11 matched anticoincidence counters, the latest design Libby screen wall counter, an electronic circuit containing separate voltage supplies for each set of counters, a scale-of-two circuit and a recording apparatus, together with an anticoincidence circuit. Special techniques have been developed to assure low background.

Equipment for determining age of archeological specimens by measuring their residual carbon radioactivity by the use of cosmic-ray counters



Courtesy of Radiation Counter Laboratories, Inc

Simplified Strain-Gauge Technique Aids Aircraft Propeller Design

Scientists at Armour Research Foundation of Illinois Institute of Technology, Chicago, are helping to make air travel safer, faster, and cheaper. By developing a new and better method of measuring and recording the strains to which aircraft propellers are subjected in flight, Foundation electronics researchers have simplified some of the intricate design problems faced by aeronautical engineers.

Not only is the new Foundation strain-measuring technique simpler, but it is more sensitive to minute changes in propeller strain, and it also provides information which is freer from certain types of electrical interference. The new technique, and its associated electronic equipment, were developed by Foundation scientists for the United States Air Force specifically to meet the needs for improved propellers in military airplanes. However, its applications extend into civil aircraft propeller design, as well as into many other types of strain measurement where a high degree of accuracy and ruggedness are necessary.

In operation, the system utilizes conventional strain gauges placed on propellers. Under test conditions, with propellers under strain, the outputs of the strain gauges are fed through slip rings on the propeller shaft into a 170-tube electronic amplifying and recording device.

In conventional strain-measuring equipment, at least one slip ring had to be used by researchers for each strain gauge. With the new Foundation system, the number of slip rings has been reduced by more than 50 per cent by connecting the gauges in series rather than individually.

Another improvement has been accomplished by utilizing voltage pulses to energize the strain gauges, rather than the direct current which has been used previously. These pulses, because they are applied for only a fraction of a second, can be much higher in voltage than if they were a constantly applied direct current. Actually, these pulses occur thousands of times each second.

It is this ability to apply higher voltages to the strain gauges which results in the increased sensitivity of the Foundation-developed measuring system.

More Emphasis on Basic Science Needed by Engineering Schools

A plea that all engineering schools should devote themselves to ways of making substantial improvements in their courses of study was made by the Committee on Adequacy and Standards of Engineering Education of the Engineers' Council for Professional Development (ECPD), as a result of an extensive study made by this committee. Chairman S. C. Hollister, Dean of Engineering, Cornell University, reporting for the committee, said: "It becomes clear that there is going to be a shortage of engineers for many years to come. At such a time, in the national interest, it is of paramount importance that the best possible education in engineering be provided by our schools. Each man is going to be called upon to cover a greater range than heretofore, if the engineering needs are to be met. Every school should devote itself to ways of substantial improvement of its program, to the end that its graduates will meet the responsibilities being placed upon them."

Tracing the history of engineering education, the committee pointed out that emphasis on engineering arts rather than engineering science, which is all too prevalent in the engineering colleges, results in rapid obsolescence of the methods and information learned whereas education predicated on science and the engineering approach will sustain the engineer for his lifetime. Because educators should be preparing students for professional work that will reach a maximum culmination 20 or more years hence, courses least likely to obsolesce should be given.

Into this category the committee placed mathematics as the outstanding example. However, all basic sciences, if taught in a manner such that knowledge of them makes available working tools, will be a sustaining part of the curriculum.

According to the committee the pressure upon engineering schools to provide general education in addition to an increased scientific and technical training brings them constantly face to face with the limitation in time imposed by the conventional curriculum. "Other professions have had to face this issue," stated the committee. "If engineering maintains professional stature, it will have to organize accordingly."

Modern Network Synthesis to Be Subject of Symposium

Modern Network Synthesis (audio to microwaves) is the subject of a symposium to be held on April 16, 17, and 18, 1952, at the Engineering Societies Building Auditorium, 33 West 39 Street, New York, N. Y. This symposium, jointly sponsored by the Polytechnic Institute of Brooklyn (N. Y.) and the Office of Naval Research, will summarize the progress to date in the various fields of network synthesis and highlight new developments of current interest to engineers and physicists. American and European authorities, who have contributed to the art, will participate.

No registration fee will be charged for admission to this symposium. Proceedings of the Modern Network Synthesis Symposium will be published by September 1952, at a cost of four dollars ($4) per copy. Orders for the Proceedings, accompanied by check or money order made out to "Treasurer, Network Symposium," will be accepted in advance. Copies of the detailed program, hotel accommodation information, and registration forms are available on request. All correspondence should be addressed to: Polytechnic Institute of Brooklyn, Microwave Research Institute, 55 Johnson Street, Brooklyn 1, N. Y.

Michigan State College to Hold Conference on Nuclear Energy

Development of an educational program designed to spread information on the facts and future of atomic energy was announced recently by Michigan State College, East Lansing. College officials said the first phase of the program would be a 2-day conference titled "Atomic Energy and the Future" scheduled for May 20–21. Specialists in peace-time usage of atomic energy from the Atomic Energy Commission's Argonne National Laboratory, Chicago, Ill., have been invited to take part. Invitations also have gone out to nuclear energy experts from the Massachusetts Institute of Technology and the University of North Carolina.

Emphasis in the conference will be placed on possible uses of atomic energy in industry for power generation. All sessions will be opened to the general public. Further information may be obtained from Professor D. J. Renwick, Mechanical Engineering Department, who is program chairman, or from Stanfield Wells of the Continuing Education Service, Michigan State College, East Lansing, Mich.

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

ANALYSIS OF ELECTROPLATING AND RELATED SOLUTIONS. By Kenneth E. Langford. Electroplating and Metal Finishing, Teddington, Middlesex, England, 1951. 387 pages, diagrams, tables, $8^3/_4$ by $5^3/_4$ inches, cloth, $5. More than 300 methods are given for the determination of principal constituents and impurities, indexed and cross-referenced for the most effective use. The book also covers sampling, the control of cleaners, pickles, dips, etches, and so on, the analysis of plating salts and of water, physical and physico-chemical methods of analysis, and the preparation of standard solutions for volumetric analysis. Considerable manipulative detail is given, the significance of analyses and the limitations of methods are indicated, and a useful selection of technical data tables is included.

ALTERNATING-CURRENT MACHINES. By George V. Mueller. McGraw-Hill Book Company, 330 West 42d Street, New York 18, N. Y., first edition, 1952. 502 pages, illustrations, diagrams, charts, $9^1/_4$ by $6^1/_4$, cloth, $7.50. A textbook for an undergraduate course in a-c machines or for use by one beginning the study of the subject. The author is professor of electrical engineering at Purdue University.

ELIAS E. RIES, INVENTOR. By Estelle H. Ries. Philosophical Library, 15 East 40th Street, New York 16, N. Y., 1951. 369 pages, $9^1/_4$ by $5^1/_2$ inches, cloth, $4.75. This story, by the daughter of one of the pioneers of electrical development, gives a behind-the-scenes account of some of the Ries inventions which included, among many others, basic patents on a-c generation and transmission for electric railroads, motor starting and controlling, railway signals, electric welding, and the photographing of sound on film. The many difficulties of promotion and sale of the inventions is emphasized.

THE MEASUREMENT OF RADIO ISOTOPES. By Denis Taylor. (Methuen's Monographs on Physical Subjects.) John Wiley and Sons, Inc., 440 Fourth Avenue, New York 16, N. Y., 1951. 118 pages, charts, diagrams, tables, $6^3/_4$ by $4^3/_4$ inches, cloth, $1.50. Written for the nonspecialist, this small volume summarizes the main phenomena and techniques of radioactivity and outlines the more important experimental methods used for the detection and assay of radioactive materials. The emphasis is on physical principles and the advantages and limitations of methods and instruments are explained.

THE NON-DESTRUCTIVE TESTING OF METALS. By R. F. Hanstock. The Institute of Metals (Monograph and Report Series Number 10), 4 Grosvenor Gardens, London, S. W. 1, England, 1951. 163 pages, charts, diagrams, illustrations, tables, $8^3/_4$ by $5^1/_2$ inches, cloth, $3.50. In this monograph consideration is given not only to the well-known radiographic, magnetic, and ultrasonic methods but also to other available methods of examination with the object of providing a reference work giving alternative approaches to special problems. To this end the limitations within which a test may be expected to operate successfully are indicated carefully. Test classifications dealt with are thickness measurements, surface finish, defect detection, composition analysis, mechanical properties, and physical state.

PROCEEDINGS OF THE THIRD ANNUAL INDUSTRIAL ENGINEERING INSTITUTE. Published by the University of California, Berkeley 4, Calif., 1951. 82 pages, charts, diagrams, illustrations, tables, $10^3/_4$ by $8^1/_2$ inches, paper. The 17 papers included in this publication deal with the following topics: work-factor aspects; methods-time measurement; production estimating; time study rating; operational studies; personnel handling; and union problems in setting production standards. The presentation of some of the papers was accompanied by the showing of films. These films have been made available for purchase.

RADAR AND ELECTRONIC NAVIGATION. By G. J. Sonnenberg. D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York, N. Y., 1951. 272 pages, charts, diagrams, tables, $8^3/_4$ by $5^1/_2$ inches, cloth, $6.00. Although basic principles are discussed for all the systems covered, the emphasis is placed on those factors of operation and interpretation which are of practical use and importance to the navigator. Following the general introduction the book is divided into sections dealing respectively with the Decca system, the loran system, the Consol system, echo sounders, and radar.

RESISTANCE STRAIN GAUGES. By J. Yarnell. Electronic Engineering, London, England, 1951. 128 pages, charts, diagrams, illustrations, 9 by $5^3/_4$ inches, cloth, 12s6d. The construction and mounting of strain gauges are described, the theory underlying their use and the circuits and equipment needed are covered in detail, and the analysis and interpretation of results are demonstrated. The auxiliary use of strain-sensitive lacquers is discussed also.

THERMODYNAMICS (Methuen's Monographs on Physical Subjects). By Alfred W. Porter. John Wiley and Sons, Inc., New York, N. Y., fourth edition, 1951. 124 pages, diagrams, $6^3/_4$ by $4^1/_4$ inches, cloth, $1.50. The opening chapter of this small book gives a historical account of the laws and other basic aspects of thermodynamics. The remaining four chapters present the text material under the following headings: reversible changes; miscellaneous applications; irreversible operations; on equilibrium.

TV AND ELECTRONICS AS A CAREER. By Ira Kamen and Richard H. Dorf. John F. Rider, Publisher, Inc., 480 Canal Street, New York 13, N. Y., 1951. 326 pages, illustrations, $8^1/_2$ by $5^1/_2$ inches, cloth, $4.95. The authors first describe the detailed workings of each phase of the industry—broadcasting, manufacturing, engineering, sales—followed by the story of how each individual contributes to the over-all operation, how much he is paid, how to get the job, the training needed, and the future outlook. A chapter is devoted to the opportunities for electronic technicians in the Armed Services.

TELEVISION ENGINEERING. By Donald G. Fink. McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 18, N. Y. Second edition, 1952. 721 pages, charts, diagrams, illustrations, $9^1/_4$ by $6^1/_4$ inches, cloth, $8.50. Information is given not only on the fundamental processes of television transmission and reception but also on design and modern equipment including practical working diagrams of all functional elements of the television system from camera to home receiver. Intended as an all-purpose text, the revised edition has been brought fully up to date and now includes two new chapters on color television systems.

TOP-MANAGEMENT ORGANIZATION AND CONTROL. By Paul E. Holden and others. Published for the Stanford University Graduate School of Business by McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 18, N. Y., 1951. 257 pages, charts, $9^1/_4$ by $6^1/_4$ inches, cloth, $5.00. In this research study of management policies and practices the material has been drawn from the investigation of 31 leading industrial concerns operating in several of the major industrial fields. The study, as indicated, is restricted to top-management problems, and simply records what seem to be the most effective and generally applicable plans and devices found. The considerably detailed information presented was gained through field interviews and a copy of the data sheet used is appended.

200 MILES UP. THE CONQUEST OF THE UPPER AIR. By J. Gordon Vaeth. The Ronald Press Company, 15 East 26th Street, New York 10, N. Y., 1951. 207 pages, charts, diagrams, illustrations, $9^1/_2$ by $6^1/_4$ inches, cloth, $4.50. A factual account and explanation of modern scientific research on the nature of the atmosphere at altitudes beyond the present range of piloted flight. It describes the plastic sounding balloons and high-altitude rockets now in use, their operation, and their contribution to the research work, as well as the instruments carried in them. The object is to provide a nontechnical but accurate summary for the interested engineer, scientist, or layman.

WORLD RAILWAYS. 1950–1951. Edited and compiled by Henry Sampson. Rand McNally and Company, 536 South Clark Street, Chicago 5, Ill., 1951. Various pagings, charts, diagrams, illustrations, tables, $8^1/_2$ by 13 inches, cloth, $25.00. Intended as a companion volume to reference works such as Jane's Fighting Ships and Jane's All the World's Aircraft, it includes route mileage, number of locomotives and cars, train control and signalling devices, illustrations and abridged specifications of locomotives and cars, and other information, arranged by country, and within the country by railway systems.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

The Role of Engineering in Nuclear Energy Development. A report of the proceedings of a symposium on nuclear engineering held at the Oak Ridge National Laboratory in September 1951. Sponsored jointly by the Oak Ridge National Laboratory, The Oak Ridge Institute of Nuclear Studies, and the American Society of Engineering Education to accelerate the spreading of education in nuclear engineering in the nation's technical schools so that United States' industry may participate more fully in, and derive greater benefits from, the Atomic Energy Program. $1.40 each. Available from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C.

National Electrical Manufacturers Association Standards for Electric Power Connectors. This revision of a previous publication contains standards for the current ratings of bare copper and aluminum conductors; rated frequency; basis of temperature rise; identification marking; thread dimensions; and bolts, nuts, and lockwashers for connectors. Information is given also concerning the temperature rise, resistance, strength, and radio influence voltage tests. $2.00. Publication *Number SG-1952*, available from the National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y.

American Standard for Physical Specimens of Surface Roughness and Lay. A guide to designers, inspectors, and specification writers in designating the type of surface desired on industrial products, more particularly those with machined surfaces. Two types of physical specimens are described. One type for general purpose specimens blocks—blocks which represent typical machined flat surfaces as actually produced in the shop. The other type of block is used for precision reference work such as checking the calibration of surface roughness measuring instruments and is not intended to represent surfaces as produced in the shop by actual machining operations. The American Society of Mechanical Engineers and the Society of Automotive Engineers sponsored the development of the standard under the procedures of the American Standards Association. Available from the American Standards Association, 70 East 45th Street, New York 17, N. Y.

Calibration of Commercial Radio Field-Strength Meters at the National Bureau of Standards (NBS). Describes the standards and methods used in NBS calibration of meters in the frequency range 10 kc to 300 megacycles. Explanation given of the measurements as performed in terms of sinusoidal voltages or currents and discussion of the accuracies of the various parts of the calibration for different portions of the frequency range investigated. Available for 10 cents from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C.

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Phantom view shows G & W type "ATA" 161 kv. pothead. Background installation shows G & W type "ATA" 115 kv. potheads.

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INDUSTRIAL NOTES ....

Kingston to Direct Atomic Division at Sylvania. Walter E. Kingston has been appointed director of the new Atomic Energy Division of Sylvania Electric Products, Inc., and will head the company's expanded program of research and development in the field of nuclear reactor materials for the Atomic Energy Commission. The company has also set up a new Executive Department to supervise the planning of plant expansion and has placed Vice-President C. A. Haines in charge as director of facilities planning. Sylvania has also announced the appointment of Matthew D. Burns as general manager of their radio tube division.

New President at Federal Telephone. Henry C. Roemer, formerly Executive Vice-President of Federal Telephone and Radio Corporation, has been elected President.

Lear Elects Vice-President. George K. Otis has been elected a Vice-President of Lear, Inc. Mr. Otis will also continue as general manager of the LearCal Division of the company at Los Angeles, Calif.

Sola Appoints Vice-President. Hans U. Hjermstad has been made a Vice-President in charge of engineering of the Sola Electric Company.

Minnesota Mining Promotes Five Executives. The Minnesota Mining and Manufacturing Company has announced the following promotions: Louis F. Weyand has been made Executive Vice-President; Robert W. Young has been made Chairman of the Board of the Minnesota Mining and Manufacturing International Company, a wholly owned subsidiary of the parent company; Clarence B. Sampair has been named President of that same subsidiary; and George W. Swenson and Hubert J. Tierney have both been appointed Vice-Presidents of the parent company.

Westinghouse Elects Two Vice-Presidents, Reassigns Others. The Westinghouse Electric Corporation has reassigned Vice-President Tom Turner, putting him in charge of the motor and control division at Buffalo, N. Y., and Vice-President T. I. Phillips has succeeded Mr. Turner as staff Vice-President in charge of manufacturing. Elected Vice-Presidents by the company's Board of Directors are Robert D. Blasier, Vice-President in charge of industrial relations and a member of the President's headquarters staff, and John E. Payne, Vice-President in charge of the company's central sales district.

(*Continued on page 28A*)

When Your Problem is ELECTRICAL PORCELAIN... it pays to put it up to Pinco, as the users of this transformer bushing can testify. With Pinco engineering help they get a design that does the job with protection to spare ... and can be produced speedily and economically in Pinco's modern plant. And ... they get Pinco Porcelain, unexcelled for electrical and mechanical strength!

For the same help on other transformer bushings for other voltages, current and construction or any other special electrical porcelain with or without metal parts—put your problem up to Pinco! Inquiries welcomed.

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Again Philco leads the way . . . with Philco *Advanced Design* Microwave Communications Systems. Philco's years of experience in microwave development has produced a system unsurpassed in reliability, performance and economy.

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(*Continued from page 16A*)

Meola Elected Vice-President of RCA Communications. Thomas D. Meola has been elected Vice-President in charge of the New York district of RCA Communications, Inc.

Hawthorne Named Secretary-Treasurer at Weston. F. G. Hawthorne has been made Secretary and Treasurer of the Weston Electrical Instrument Corporation.

Changes Made at International Telephone and Telegraph. The following changes in the headquarters staff of the International Telephone and Telegraph Corporation have been announced: W. H. Pitkin, Vice-Chairman and general attorney, has relinquished his position as general attorney and has been appointed counsel for the corporation. He will continue to serve as Vice-Chairman. Charles D. Hilles, Jr., Vice-President and Secretary, becomes Vice-President and general attorney. Geoffrey A. Ogilvie, formerly Vice-President in charge of telephone operations, has been named Vice-President and Secretary.

Ford Instrument Names Vice-President. Robert R. Porter has been made Vice-President and sales manager of the Ford Instrument Company Division of The Sperry Corporation.

Aluminum Output Up Over 16 Per Cent in 1951. The Aluminum Association has announced that in 1951 there was an increase of 16.5 per cent over the previous year's output, and that the final 1951 quarter outproduced the same period in 1950 (382,176,940 pounds) by more than 52,000,000 pounds.

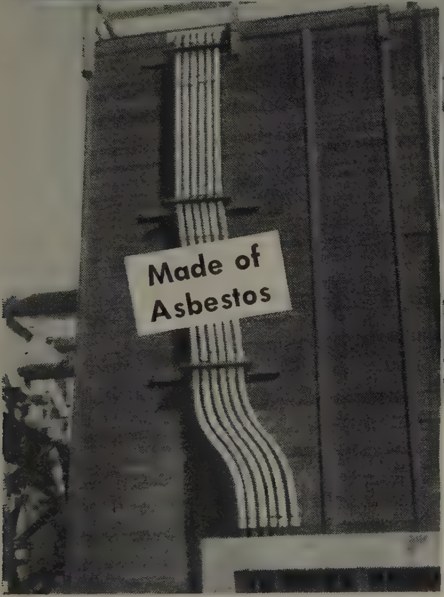
New Allis-Chalmers Appointments. H. Stanley Bimpson has been appointed chief engineer of Allis-Chalmers Manufacturing Company's steam turbine section, succeeding the late E. H. Horstman; Charles D. Wilson has been named engineer in charge of steam turbine design; and Joe C. Pohlman has been made application engineer, transformer section, in charge of regulator sales for the southwest and central regions.

Du Mont Promotes Rosenberg, Rice. Irving G. Rosenberg has been appointed director of operations, responsible for Allen B. Du Mont Laboratories, Inc.'s television receiver and cathode-ray tube divisions, and Fritz P. Rice has been named manager of the cathode-ray tube division.

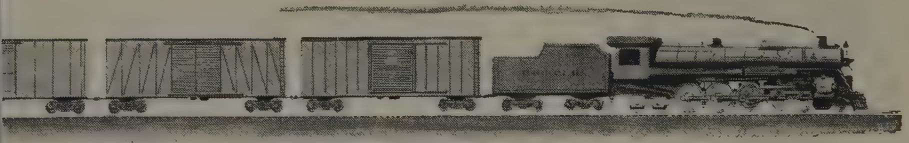
G-E News. The General Electric Company has made the following new appointments: Thomas Sproule has been named manager of manufacturing of the company's Welding Department in Fitchburg, Mass.; Ernest A. Wagner has been made manager of engineering for the company's Allentown, Pa., plant; Henry F. DeLong has been appointed manager of lamp

(*Continued on page 30A*)

Installed over 18 years ago on this bridge, Transite Conduit is still on the job despite the attack of corrosive fumes, weather, and vibration.



Resists the Elements: Transite Ducts are standing up far longer than other materials on this cooling-tower wall despite corrosive conditions. Transite's exceptional corrosion-resistance practically eliminates maintenance and replacement costs through the years.



That's why TRANSITE® DUCTS stay on the job despite corrosive fumes, soils and weather

If you're looking for a conduit that will stand up for years in tough service . . . use Transite Ducts that not only resist corrosion but are immune to electrolysis, too.

Transite, you see, is made of asbestos and cement . . . two naturally corrosion-resistant materials. It stands up in corrosive cinder fills, salt marshes, and other troublesome soils. It also withstands the attack of smoke, fumes . . . and weather conditions will not shorten its service life. Since it is inorganic and nonmetallic, Transite also is immune to electrolysis or galvanic action.

You will find that Transite Ducts save you money on your cableway system not only by staying on the job longer . . . but by holding down the initial cost, too. For further information write Johns-Manville, Box 60, New York 16, N. Y.

4 OTHER REASONS WHY TRANSITE DUCTS DO A BETTER JOB AT LESS COST:

1. Incombustible. Transite will not burn or contribute to formation of smoke, gases, or fumes. It confines burnouts and protects adjacent cables.

2. Permanently Smooth Bore. Transite makes long cable pulls easy. Danger of damage to cables is also minimized.

3. Easy To Install. Transite Ducts are light weight, easy to handle. Joints are quickly made. And, long 10-foot lengths reduce the number of joints in the line.

4. Higher Thermal Conductivity. Cables run cooler in Transite Ducts, reducing I^2R losses, increasing current capacity, and prolonging insulation life.

Outlasts other Materials: When other ducts failed to stand up under the streets of a city in the Far West, Transite Ducts were installed. Their life expectancy is far greater than that of the ducts they have replaced.

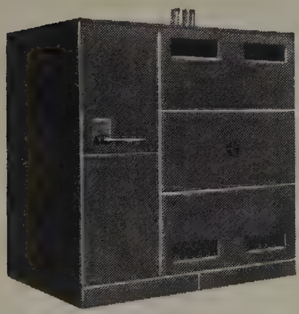
JOHNS-MANVILLE JM PRODUCTS

Johns-Manville TRANSITE DUCTS

TRANSITE KORDUCT—for installation in concrete

TRANSITE CONDUIT—for exposed work and installation underground without a concrete encasement

100 KVA Type F Transformer
2400/120/240



450 KVA, Type F Unit Substation, 4160 V. Delta, 60 Cycles, 3 Ø—120/208Y, 4 wire.

ONE OF THE WORLD'S LARGEST MANUFACTURERS OF DRY TYPE TRANSFORMERS EXCLUSIVELY

1 to 2,000 KVA up to 15,000 Volts to meet Individual Requirements

- DISTRIBUTION
- GENERAL PURPOSE
- UNIT SUBSTATION
- PHASE CHANGING
- ELECTRIC FURNACE
- RECTIFIER
- WELDING
- MOTOR STARTING
- SPECIAL

NEMA

Representatives in Principal Cities

MARCUS TRANSFORMERS CONFORM TO THE STANDARDS OF N.E.M.A. AND A.I.E.E.

Made by a pioneer in the dry type, air-cooled transformer field. Eliminate need for liquid filled units. No hazardous, inflammable oil or toxic liquid to fuss with. Maintenance of oil level, foreign matter, sludge accumulation, and subsequent filtering are relegated to the "horse and buggy days".

MARCUS DRY TYPE, AIR-COOLED TRANSFORMERS

ARE SAFE — No explosion or fire hazards. No fire proof vaults. Class B and C heat proof insulations.

ARE ECONOMICAL — Lower cost installation and operation, negligible maintenance.

For the transformer that's second to none, specify MARCUS.

MTC

MARCUS
TRANSFORMER CO.
INC.
32 MONTGOMERY STREET
HILLSIDE 5, NEW JERSEY

PIONEERS IN THE FIELD OF AIR-COOLED TRANSFORMERS

(*Continued from page 26A*)

manufacturing at Nela Park in Cleveland, Ohio; and William E. Davidson has been named manager of sales operation, also at Nela Park.

Harley Joins Sprague. John H. Harley has joined the radio interference filter group at the Culver City, Calif., application engineering laboratory of the Sprague Electric Company.

Minneapolis-Honeywell Promotes Keller. Stephen A. Keller has been named general manager of the valve division of the Minneapolis-Honeywell Regulator Company.

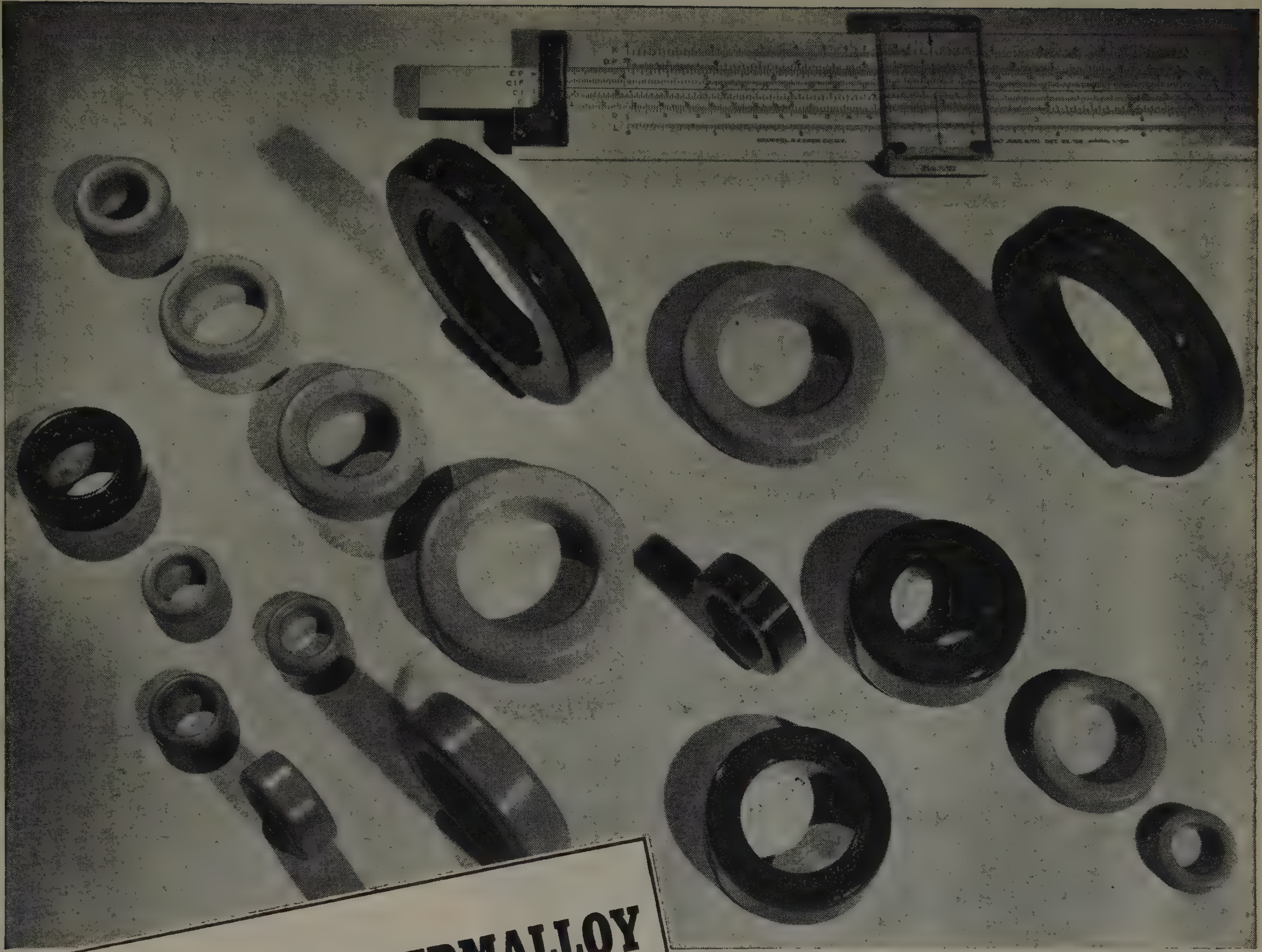
Burndy Opens New Headquarters in Norwalk. In order to increase operating efficiency and expand service facilities, the Burndy Engineering Company, Inc., has moved 300 Burndy employees from New York into the firm's recently completed administrative headquarters building occupying a 10-acre tract off the Boston Post Road in Norwalk, Conn. The new building centralizes the personnel and functions of the executive, sales, accounting, technical service, research, advertising, development, and clerical departments, and houses vastly expanded quality control and research laboratories as well.

Aircraft Electronics Consultant Firm Formed. Reinforced Plastic Consultants and Engineers, of 1603 West 135th Street, Gardena, Calif., has been organized to solve problems in the design, development, test, and analysis of radomes for air-borne radar systems. Charles E. Peach is the chief engineer for design and analysis, and Samuel S. Oleesky is chief engineer for research and development.

NEW PRODUCTS • •

Electro-larm. The electro-larm is a new type of annunciator. When an abnormal condition arises in any equipment being monitored by the electro-larm the indicator key moves to the "alarm" position, is illuminated, and an audible signal is sounded. When the abnormal condition is corrected by the operator the key moves to "clear," again sounding the audible signal to notify the operator of the clearance. The operator may now move the key back to "normal," silencing the audible signal and darkening the key. If the abnormal condition is only momentary the key may be returned to "normal" from the "alarm" position but if the condition continues the key will not latch in "normal." The bottom two terminals are connected in the power source and therefore may be bussed when units are mounted in a group. One top terminal is the audible signal connection and this too may be bussed. The only other terminal is for connection to the remote sensing adjunct, the return of which is to the power source. Electro Devices, Inc.,

(*Continued on page 36A*)



MOLYBDENUM PERMALLOY POWDER CORES*

(New technical data now available)

HIGH Q TOROIDS for use in Loading Coils, Filters, Broadband Carrier Systems and Networks—for frequencies up to 200 KC

COMPLETE LINE OF CORES TO MEET YOUR NEEDS

★ Furnished in four standard permeabilities—125, 60, 26 and 14.

★ Available in a wide range of sizes to obtain nominal inductances as high as 281 mh/1000 turns.

★ These toroidal cores are given various types of enamel and varnish finishes, some of which permit winding with heavy Formex insulated wire without supplementary insulation over the core.

For high Q in a small volume, characterized by low eddy current and hysteresis losses, ARNOLD Moly Permalloy Powder Toroidal Cores are commercially available to meet high standards of physical and electrical requirements. They provide constant permeability over a wide range of flux density. The 125 Mu cores are recommended for use up to 15 kc, 60 Mu at 10 to 50 kc, 26 Mu at 30 to 75 kc, and 14 Mu at 50 to 200 kc. Many of these cores may be furnished stabilized to provide constant permeability (±0.1%) over a specific temperature range.

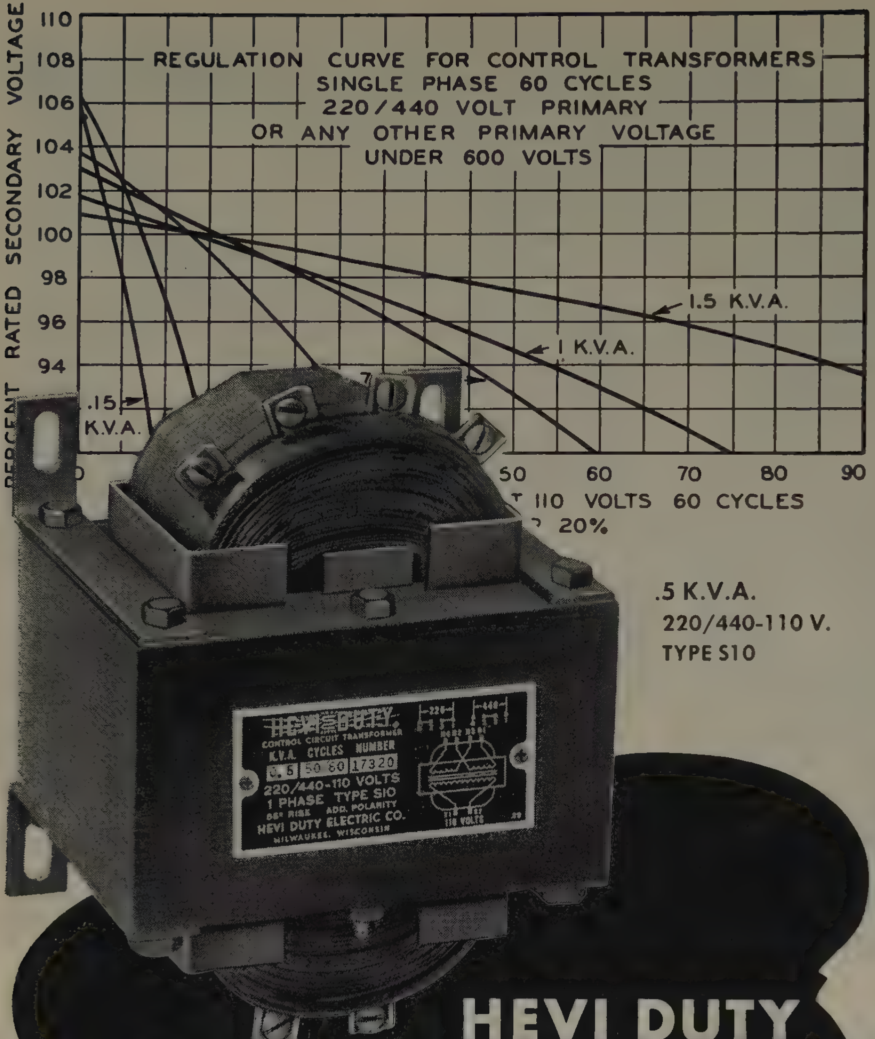
*Manufactured under license arrangements with Western Electric Company

W&D 4127

THE ARNOLD ENGINEERING COMPANY

SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

General Office & Plant: Marengo, Illinois



HEVI DUTY CONTROL CIRCUIT TRANSFORMERS

For Machine Tool and Other Industrial Controls

Hevi Duty control circuit transformers are specified by many machine tool and control manufacturers because of their superior and dependable performance. They are designed specifically for control circuits where high in-rush currents occur to provide better regulation of circuit voltage.

Write for Bulletin T-5111 for more complete information. This bulletin shows regulation curves, impedance characteristics, and presents other engineering data.

Hevi Duty control circuit transformers are designed to meet or exceed NEMA, ASA and JIC standards.

HEVI DUTY®

HEVI DUTY ELECTRIC COMPANY

MILWAUKEE 1, WISCONSIN

Heat Treating Furnaces ... Electric Exclusively

Dry Type Transformers *Constant Current Regulators*

(*Continued from page 30A*)

developer of this device, at 4025 Easton Avenue, St. Louis 13, Mo., will supply any further details.

Electronic Pilot Relay. The Haledy Electronics Company, 57 William Street, New York 5, N. Y., has announced development of an electronic pilot relay, capable of controlling large values of current and power with a current flow of 2 microamperes through the utilization of an unusual cold-cathode tube of unlimited life. This minute flow of current permits delicate mechanisms with extremely light contact pressures to control large electric currents. The cold-cathode triode tube (*TT-1*) is designed for use under the most rugged conditions. It has no heater filament, and will operate over any input resistance from a dead short to 10 megohms, with leads of unlimited length. Current amplification is up to $2^1/_2$ million. Utilizing a 115-volt 60-cycle line source, the relay consumes 2 watts when in operation. The Haledy Electronics Company will furnish any further information.

Random Noise Generator. Typical applications of a new type *1390-A* random noise generator developed by the General Radio Company include room acoustics measurements, loudspeaker and microphone tests, psychoacoustic tests, filter tests, calibration checks on recording systems, observations of resonances and electrical averaging of resonant responses, comparisons of effective bandwidth, and crosstalk measurements on multichannel systems. A gas-discharge tube operated in a magnetic field is the noise source. Two stages of amplification and suitable filters make it possible to have an open-circuit output voltage of one volt on the three frequency ranges, extending from 30 cycles to 20 kc, 500 kc, or 5 megacycles. Maximum open-circuit output voltage on any of the three bands is about 1 volt rms. Source impedance for maximum input is approximately 800 ohms; output is taken from a 2,000-ohm potentiometer. Power supply is 115 (or 230) volts 50 to 60 cycles. Total power consumption is about 50 watts. The General Radio Company, 275 Massachusetts Avenue, Cambridge 39, Mass., will supply any additional information.

Meter Matcher. The model *105* meter matcher designed by Keithley Instruments is a power frequency amplifier for greatly reducing the errors caused by instruments which load a circuit under test. Use of this instrument relieves a test circuit from supplying the usual power to the measuring voltmeter or wattmeter; errors caused by meter currents can thus be eliminated. The meter matcher input is connected to a test circuit, and its output connected to a voltmeter or the voltage coil of a wattmeter. The amplifier's input impedance requires a maximum of 150 microamperes from the circuit being tested. Its output provides the 0.05 to 0.07 ampere which most accurate dynamometer instruments require for full-scale deflection. Input

(*Continued on page 52A*)

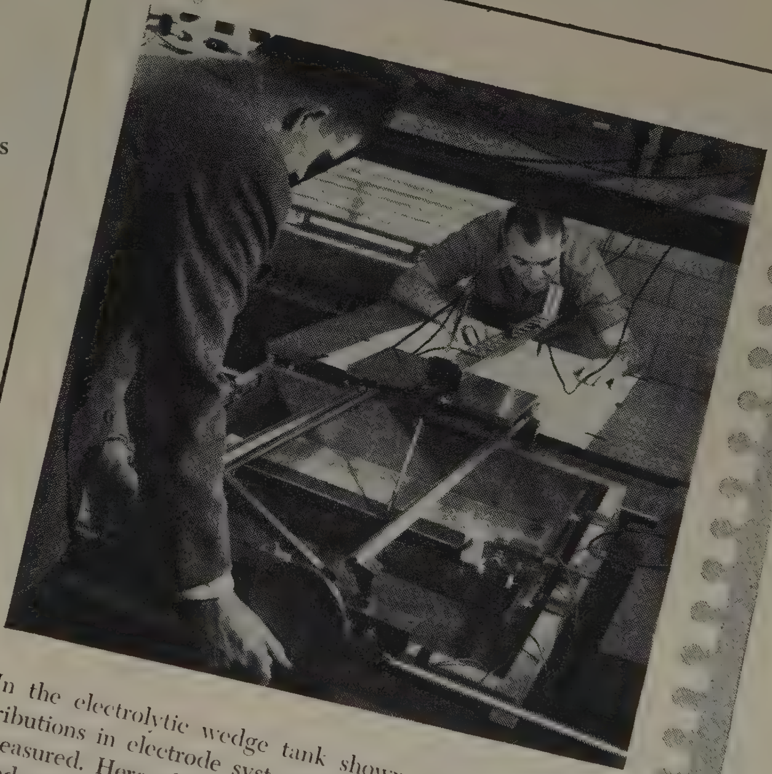
A page from the note-book of Sylvania Research

Pre-Determining CRT Electrode Configurations Saves Experimental Costs

An electrolytic tank and an ingenious plotting system give engineers at Sylvania's Research Laboratories great flexibility in the design of electron guns for cathode ray tubes.

An enlarged scale model of a vacuum tube electrode system is immersed in an electrolyte and voltages in proper ratio are applied to the electrodes. The potential distribution which results is that of the original electrode system in the vacuum tube.

With this tank various electrode configurations can be investigated and results plotted without expensive and time consuming assembly of endless sample tubes. With data gathered desired tubes having predetermined characteristics can be constructed for further tests. Development of such methods and equipment by Sylvania contributes much to the continuous improvement of Sylvania cathode ray tubes for television and other applications.



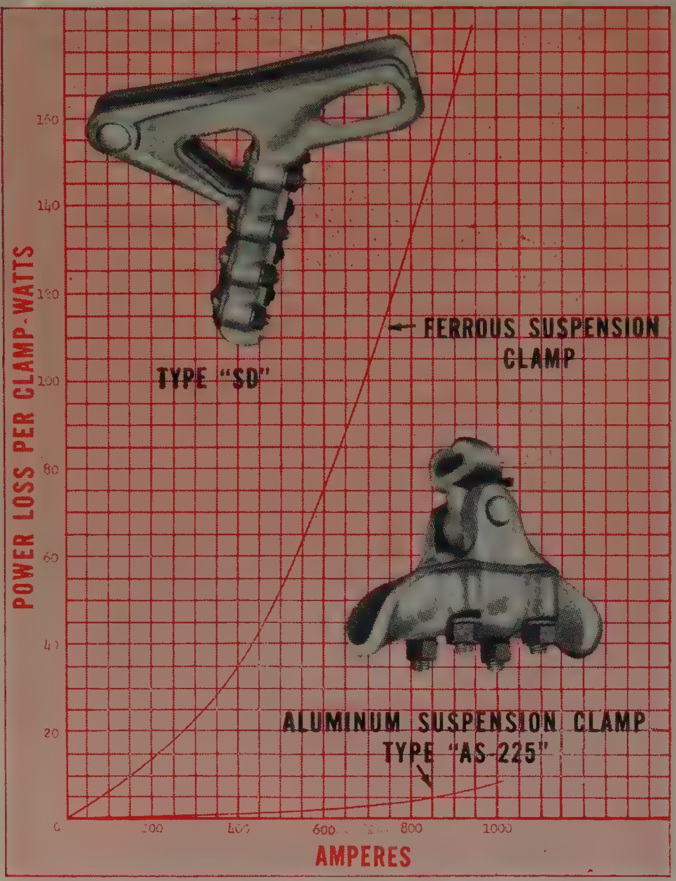
In the electrolytic wedge tank shown, the potential distributions in electrode systems of rotational symmetry are measured. Here, the sides of a wedge section of the electrode system are represented by the top and bottom surfaces of the water; the axis, by the water line; the cylindrical electrodes, by flat electrodes (as the wedge angle is small).

SYLVANIA

Sylvania Electric Products Inc., 1740 Broadway, New York 19, N. Y.

TELEVISION PICTURE TUBES; ELECTRONIC TEST EQUIPMENT; ELECTRONIC PRODUCTS; RADIO TUBES; FLUORESCENT TUBES, FIXTURES, SIGN TUBING, WIRING DEVICES; LIGHT BULBS; PHOTOLAMPS; TELEVISION SETS

MORE POWER
DELIVERED WITH LESS MAINTENANCE...



Backed by many years of coordinated electrical, mechanical and metallurgical engineering knowledge and experience in the design and manufacture of cast aluminum products for the electrical industry.

USE CAST ALUMINUM
TYPE "AS" SUSPENSION AND TYPE "SD" STRAIN CLAMPS
ON ALUMINUM TRANSMISSION LINES

STOP—Hysteresis and eddy current power losses.

PREVENT—Corrosion, heating and annealing damage to conductor within clamps.

ELIMINATE—Jumper splice failures—use through conductor strain clamps with continuous jumpers at strain points.

BE SURE—SPECIFY—Cast aluminum clamps with more than 25% greater strength.

WRITE FOR
Catalog No. 320

Consult one of our nearest 17 representatives or contact our main office.

OUR PRODUCTS ARE QUALITY CONTROLLED
FROM INGOT TO FINISHED PRODUCT

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Birmingham, 1, Alabama

• BRONZE AND ALUMINUM POWER CONNECTORS, FITTINGS, AND BUS SUPPORTS
ALUMINUM SUSPENSION AND STRAIN CLAMPS

(Continued from page 36A)

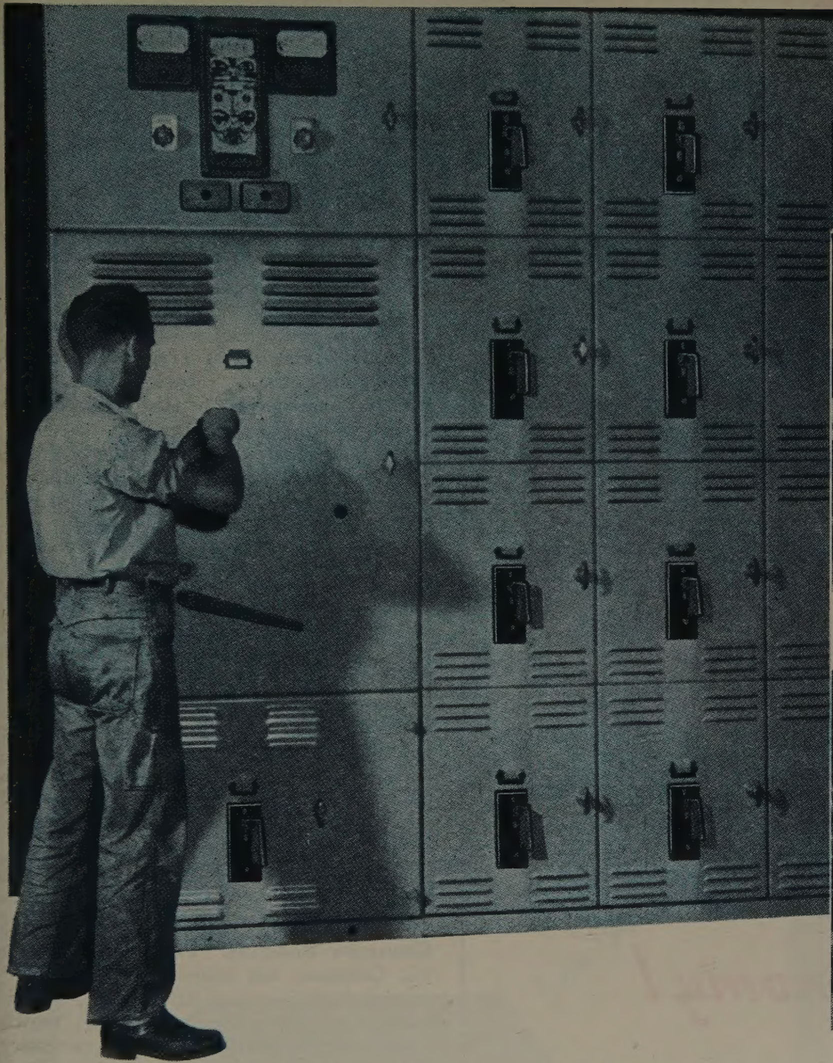
connections for 15-, 75-, 150-, 300-, and 600-volt inputs are provided, and in each case the output is 150 volts. The meter matcher will develop 150 volts rms across a 2,000-ohm resistive meter load, and adds only a 0.15 per cent maximum error to the measurements. A large amount of negative feedback is used to reduce the effective output impedance to approximately 1 ohm in series with 15,000 microfarads. Keithley Instruments, 3868 Carnegie Avenue, Cleveland 15, Ohio, will supply any additional details desired.

Plastic-Cased Batteries. Gould-National Batteries, Inc., Trenton 7, N. J., has announced a new line of plastic batteries for use in telephone installations, alarm systems, power-plant control systems, and other applications where batteries are used for stand-by emergency power. Capacity range is from 10 to 100 ampere-hours (at the 8-hour rate of discharge). These transparent polystyrene containers do not react with electrolyte and have better shock resistance than glass containers. Additional information is available from the company.

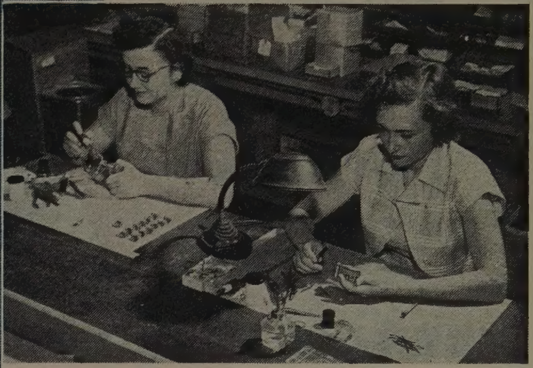
Rectifier for Jets. A regulated selenium rectifier providing direct current for both jet-engine starting and radio-radar check-out is being manufactured by Inet, Inc. The pneumatic-tired ground power unit supplies a continuous d-c output of 1,500 amperes at 28 volts. Automatic controls provide voltage regulation at better than ±0.25 per cent from no load to full load with up to ±10 per cent a-c line fluctuation. A multiposition selector switch allows the operator to select the necessary voltage current characteristic for particular setting or engine starting needs. One model provides dual outputs—one giving constant potential to maintain the ship's electric equipment while the other simultaneously provides constant current for jet starting. Inet, Inc., 8655 South Main Street, Los Angeles, 3, Calif., will furnish additional information.

Alternate Ringer Arrangement Saves Cobalt Steel. A new type of telephone subset rectifier ringer that eliminates the use of vitally-needed cobalt steel as the polarizing permanent magnet in telephone receivers has been developed by Federal Telephone and Radio Corporation. Designed primarily for use in their telephone subsets the new ringer utilizes a small selenium rectifier of two cells 7 millimeters in diameter so connected in the circuit that current is applied alternately to each magnet coil of the ringer. Since the complete elimination of the cobalt steel magnet would leave the magnetic circuit incomplete it has been replaced by an annealed low-carbon steel pole piece. This redesigned rectifier ringer performs satisfactorily with the $16^{2}/_{3}$—35 cycles per second range over subscribers' loops up to approximately 1,400 ohms when not more than four ringers are bridged on a line and when the minimum voltage of the

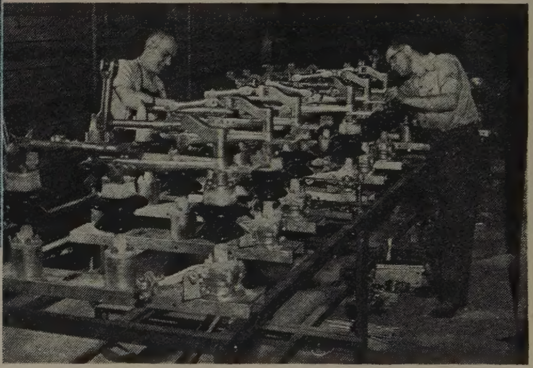
(Continued on page 64A)



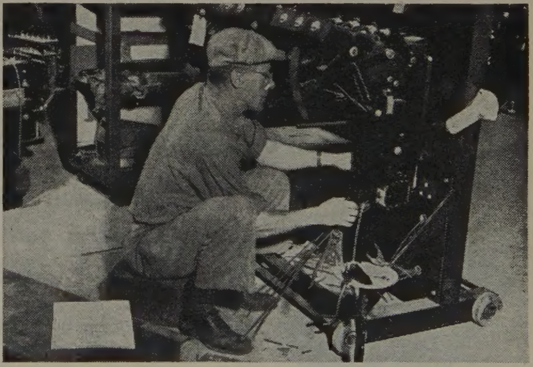
Final assembly of custom-built, low voltage, metal-clad switchgear.



Skilled workers assemble precision instruments.



Assembling Duo-Roll air break switches.



Workman wiring large air circuit breaker.

inside story!

Last April we opened an additional plant in Bethlehem, Pennsylvania. It is not only our newest but our largest. Because of this, we've been able to greatly increase our production of the precision-designed, dependable electrical equipment for which Roller-Smith and Elpeco have been noted since the early 1900's. We are happy to be in a position to supply increased amounts of equipment at a time when it is so badly needed and do it in a relatively short time. Despite universal material shortages and our greatly increased production you can be sure, that we . . . on the "inside" . . . are maintaining our same high standard of quality. If you need superior electrical equipment, either for yourself or as part of a defense order, contact us at once. We can't promise everything you might need, but perhaps we can help solve some of your particular problems in a surprisingly short time.

ROLLER SMITH

ELPECO

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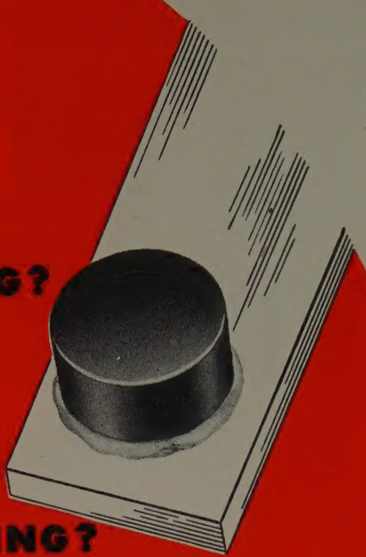
MANUFACTURERS OF

ROLLER-SMITH Oil and Air Circuit Breakers • High and Low Voltage Switchgear • Unit Substations • Instruments • Precision Balances • Watthour Meters

ELPECO Disconnect Switches • Outdoor Hook Stick Switches • Air Break Switches • Indoor and Outdoor Bus Supports • Bus Ducts • Substations



SOLDERING?

ELECTRIC BRAZING?

WELDING?

RIVETING?

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FACTORY-ATTACHED CONTACTS

spell real economy!

What is the best way to attach a certain contact material to contact arms of another material for use in certain equipment under certain conditions?

Stackpole not only has the answers, but likewise offers full facilities for handling this important operation in production quantities by the most suitable methods. This PLUS service to users of Stackpole contacts is a big factor in saving them money by eliminating scrap and in assuring maximum dependability for their products.

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Helpful Contact Data

Far more than a listing of Stackpole contact types, Catalog 12 contains a wealth of helpful data on contact materials and their applications. Write for yours today.

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All contact shapes and sizes in SILVER GRAPHITE • SILVER LEAD OXIDE SILVER NICKEL • SILVER MOLYBDENUM • SILVER TUNGSTEN • COPPER GRAPHITE • PRECIOUS METALS . . . *and many other materials*

(*Continued from page 52A*)

ringing current does not exceed 70 volts. Further details will be supplied by the company's Information Department located at 67 Broad Street, New York 4, N. Y.

TRADE LITERATURE

Instrument Transformer Buyer's Guide. The 1952 edition of the General Electric Company's Instrument Transformer Buyer's Guide, containing basic information, ratings, and prices of the company's complete line of transformers, has just been published. This 94-page spiral-bound publication, *GEA-4626E*, is available from the General Electric Company, Schenectady 5, N. Y., upon request.

Thermohms. The entire line of general-purpose and specialized Thermohms (resistance thermometers) which are used in plant and laboratory applications to detect temperatures between −325 and +1,000 degrees Fahrenheit with accuracies from ±0.018 to ±3.0 degrees Fahrenheit are described in a new 36-page catalogue issued by the Leeds and Northrup Company. Copies of the catalogue, *EN-S4*, "Thermohms, Assemblies, Parts and Accessories," may be obtained upon request to the Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia 44, Pa.

Connector Bulletins. The Cannon Electric Company has issued two new engineering bulletins: *LS5-1951* covers experimental switchboard and laboratory cord connectors; *GB4-1951* covers electric battery connectors used primarily for connecting and disconnecting starting equipment. Both bulletins can be obtained upon request to the Cannon Electric Advertising Department, P. O. Box 75, Lincoln Heights Station, Los Angeles 31, Calif.

Wire and Cable Calculator. A plastic calculator is available which shows at a glance the approximate weight per thousand feet of solid and stranded wire and cable with one, two, or three conductors, and on the reverse side shows the size of conduit or tubing needed for various numbers of conductors. The allowable current carrying capacities of conductors in amperes is also given. The calculator may be obtained upon request to Department *EE*, Triangle Conduit and Cable Company, Inc., New Brunswick, N. J.

Radio's Master. The 16th edition of *Radio's Master*, which contains over 1,100 pages of almost 90 per cent of the parts and equipment of the radio, electronic, and television industries, has been published. The price is $6.50. It may be obtained from United Catalog Publishers, Inc., 110 Lafayette Street, New York 13, N. Y.

Stand-by Emergency Power. Featured in the "E-M Synchronizer," number *35*,

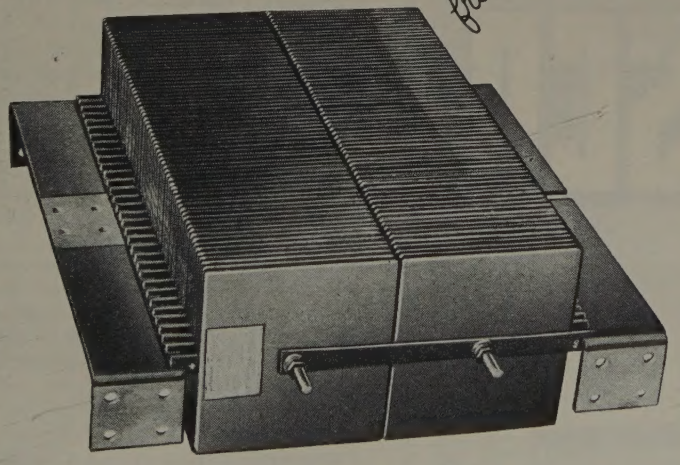
(*Continued on page 66A*)

INTERNATIONAL *Selenium Rectifiers*

HERMETICALLY SEALED RECTIFIERS
Cartridge Type—up to 60 ma., 9,000 volts per cartridge.

OUR BUSINESS IS SELENIUM RECTIFIERS *

from the largest to the smallest



POWER RECTIFIERS
Ratings up to 250 KW, Efficiency to 87%, Power Factor 95%

**and we know our business*

A recent month's production included Rectifiers to supply 40 microamperes, 1,000 volts, and Rectifiers with a capacity of 140,000 amperes, 14 volts. Owned and managed by Engineers who are specialists in the design and manufacture of Selenium Rectifiers. Submit your problems for analysis and we will be glad to offer our recommendations.

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GENERAL OFFICES:
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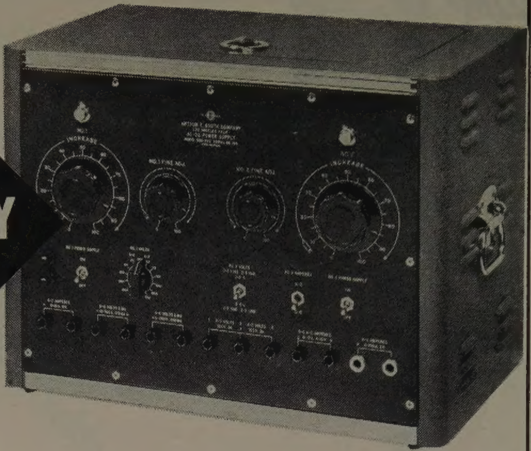
Fast, low-cost instrument and relay testing is here!

Double **your testing efficiency . . .** ***Halve*** **your testing time with this new**

BOOTH POWER SUPPLY UNIT



You save time by eliminating the need for collecting, connecting and checking the many components required. You eliminate cumbersome equipment. And you add greater safety for personnel.

Proof? Booth All-In-One Power Supply Units are in use today by leading utilities, industries and government agencies. Names on request! Write for detailed information.

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(Continued from page 64A)

quarterly publication of the Electric Machinery Manufacturing Company, 1331 Tyler Street, N. E., Minneapolis, Minn., is an article on stand-by or emergency power. Written by E. W. Kammerer, switchgear engineer for the company, this article deals with the requirements of stand-by power, types of service available, and controls for automatic start-stop operation. This special generator issue of the quarterly is available on request.

The company also is offering a reprint of a paper presented at the New York Section of the AIEE Power and Industrial Division, Motor Selection and Application Course in December 1951, entitled "Application of Direct-Connected Synchronous Motors to Reciprocating Compressors." Written by G. L. Oscarson, chief application engineer of the company, publication *1200-TEC-1111* includes formulas, sample calculations, and reference curves.

Ohm's Law Calculator. A new plastic Ohm's law calculator has been announced by the Ohmite Manufacturing Company. All Ohm's law computing scales are on the front side of the pocket-size calculator; on the back is a standard slide rule, and scales for computing parallel resistance. Price of the plastic calculator is $1.50; a similar calculator of varnished cardboard is priced at $0.25. Both are available from the Ohmite Manufacturing Company, 4937 West Flournoy Street, Chicago 44, Ill.

Compilation of Analogue Transducers. The Instrument Division of Allen B. Du Mont Laboratories, Inc., 1500 Main Avenue, Clifton, N. J., has made a compilation of over 500 different types of analogue transducers for use with cathode-ray oscillographs. The compilation is arranged alphabetically according to the transducer function. Other information given includes principle of operation, accessories required, transfer characteristics, power, amplitude range, bandwidth, and so forth. Other features are a special section tabulating Geiger-Mueller tubes, an accessory listing, and reference material quoting author and date of publication. The complete compilation may be obtained from the Instrument Division of the Du Mont Laboratories for the price of $0.50 per copy.

Temperature Controls. A 52-page catalogue (number *400*) on thermoswitch temperature controls is available on request from Fenwal, Inc., 218 Pleasant Street, Ashland, Mass.

Coal Mine Maintenance Welding. The first in a new series of "how to weld it better" manuals, titled "Coal Mine Maintenance Welding," covers the various specialized welding applications in that field. Included is a standardization chart covering over 50 different typical coal mine maintenance applications and the recommended welding alloys and data for their repair. Copies of the manual may be obtained upon request to the Eutectic Welding Alloys Corporation, Department *P*, 172d Street and Northern Boulevard, Flushing, New York 58, N. Y.